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This report, one of a series of reports concerning exposure assessment, describes methods and catalogs informations sources for estimating exposure to chemical substances in the occupational environment. The report provides specific guidance for conducting the various component analyses of an occupational exposure assessment. It details approaches used to identify chemical manufacturing, processing, and use locations, and for determining the chemical processes used. The types of monitoring data useful in occupational exposure assessments are addressed, as are relevant QA/QC considerations. The mass balance approach to estimating workplace contaminant concentrations in the absence of pertinent monitoring data is detailed, as are methods for evaluating contaminant transport and transformation in the workplace, and attendant worker exposure pathways. Procedures for identifying, characterizing, and enumerating exposed worker populations are outlined, and methods are provided for calculating the level of exposure experienced by each population. The report concludes by providing two appendices. The first details the exposure potential associated with a number of major industrial processes, while the second identifies a large number of information sources useful in conducting occupational exposure assessments.

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METHODS FOR ASSESSING EXPOSURE TO CHEMICAL SUBSTANCES

Volume 6

Methods for Assessing Occupational Exposure to Chemical Substances

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FOREWORD

This document is one of a series of volumes, developed for the U.S. Environmental Protection Agency (EPA), Office of Toxic Substances (OTS), that provides methods and information useful for assessing exposure to chemical substances. The methods described in these volumes have been identified by EPA-OTS as having utility in exposure assessments on existing and new chemicals in the OTS program. These methods are not necessarily the only methods used by OTS, because the state-of-the-art in exposure assessment is changing rapidly, as is the availability of methods and tools. There is no single correct approach to performing an exposure assessment, and the methods in these volumes are accordingly discussed only as options to be considered, rather than as rigid procedures.

Perhaps more important than the optional methods presented in these volumes is the general information catalogued. These documents contain a great deal of non-chemical-specific data which can be used for many types of exposure assessments. This information is presented along with the methods in individual volumes and appendices. As a set, these volumes should be thought of as a catalog of information useful in exposure assessment, and not as a "how-to" cookbook on the subject.

The definition, background, and discussion on planning of exposure assessments are discussed in the introductory volume of the series (Volume 1). Each subsequent volume addresses only one general exposure setting. Consult Volume 1 for guidance on the proper use and interrelations of the various volumes and on the planning and integration of an entire assessment.

The titles of the nine basic volumes are as follows:

Volume 1:	Methods for Assessing Exposure to Chemical Substances (EPA 560/5-85-001)
Volume 2:	Methods for Assessing Exposure to Chemical Substances in the Ambient Environment (EPA 560/5-85-002)
Volume 3:	Methods for Assessing Exposure from Disposal of Chemical Substances (EPA 560/5-85-003)
Volume 4:	Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances (EPA 560/5-85-004)
Volume 5:	Methods for Assessing Exposure to Chemical Substances in Drinking Water (EPA 560/5-85-005)

Volume 6: Methods for Assessing Occupational Exposure to Chemical Substances (EPA 560/5-85-006)

Volume 7: Methods for Assessing Consumer Exposure to Chemical Substances (EPA 560/5-85-007)

Volume 8: Methods for Assessing Environmental Pathways of Food Contamination (EPA 560/5-85-008)

Volume 9: Methods for Assessing Exposure to Chemical Substances Resulting from Transportation-Related Spills (EPA 560/5-85-009)

Because exposure assessment is a rapidly developing field, its methods and analytical tools are quite dynamic. EPA-OTS intends to issue periodic supplements for Volumes 2 through 9 to describe significant improvements and updates for the existing information, as well as adding short monographs to the series on specific areas of interest. The first four of these monographs are as follows:

Volume 10: Methods for Estimating Uncertainties in Exposure Assessments (EPA 560/5-85-014)

Volume 11: Methods for Estimating the Migration of Chemical Substances from Solid Matrices (EPA 560/5-85-015)

Volume 12: Methods for Estimating the Concentration of Chemical Substances in Indoor Air (EPA 560/5-85-016)

Volume 13: Methods for Estimating Retention of Liquids on Hands (EPA 560/5-85-017)

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1. INTRODUCTION

1.1 Purpose and Scope

Sections 4, 5, and 6 of the Toxic Substances Control Act (TSCA) direct the Environmental Protection Agency (EPA) to assess human and environmental exposure to toxic substances. TSCA includes provisions for EPA to obtain production and test data from industry and to regulate both new and existing substances, if necessary. This necessity is based on the risk to those involved in the manufacture, processing, distribution, use, and disposal of the chemical.

Occupational exposure assessments have historically been limited by a lack of complete and reliable data, resulting in large data gaps for some worker populations. This document presents a generalized approach to occupational exposure assessment. It specifically deals with assessment of exposure occurring as a direct result of workplace activities; exposure to outdoor workers that results from contaminants in the ambient environment is not addressed in this report. For procedures appropriate to the assessment of worker exposure to contaminants in the ambient environment, the analyst is referred to Volumes 2 and 4 of this report series, Methods for Assessing Exposure to Chemical Substances in the Ambient Environment (Freed et al. 1985) and Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances (Dixon et al. 1985), respectively.

1.2 Methodology Framework

The generalized approach to assessing worker exposure to chemicals in the occupational environment is illustrated in Figure 1-1. As the figure shows, the first step in the analysis involves determining which occupational settings are sources of exposure to workers. This includes consideration of chemical manufacturing facilities (those facilities where the chemical is produced) as well as industrial, commercial, and trade facilities that store, use, or handle the chemical or products containing the chemical. This analysis is of critical importance because it is the basis for determining the amount of chemical released to the occupational environment and for identifying and enumerating the exposed population.

Upon completion of the source determination step, it will be useful for the assessor to obtain relevant monitoring data. For occupational exposure assessments, two types of monitoring data will be helpful: personal/breathing zone monitoring data and workplace monitoring data. If no monitoring data are available, or if such data are available but are not useful in the study because of (1) problems with data quality, or (2) inability to relate the monitored values to specific sources, the

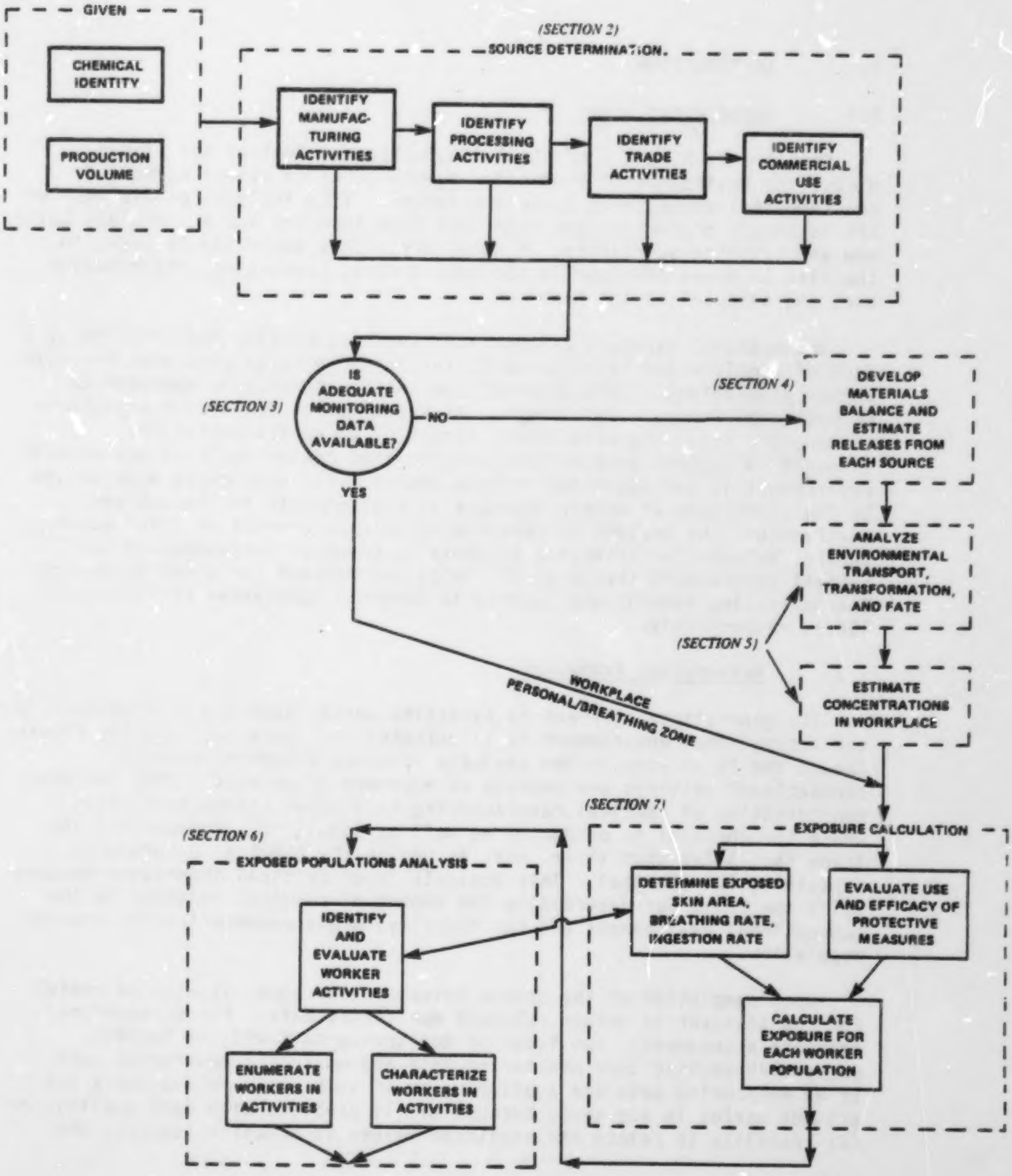
GIVEN
CHEMICAL IDENTITY
PRODUCTION VOLUME
(SECTION 2)
SOURCE DETERMINATION
IDENTIFY MANUFACTURING ACTIVITIES
IDENTIFY PROCESSING ACTIVITIES
IDENTIFY TRADE ACTIVITIES
IDENTIFY COMMERCIAL USE ACTIVITIES
(SECTION 3)
IS ADEQUATE MONITORING DATA AVAILABLE?
NO
YES
(SECTION 4)
DEVELOP MATERIALS BALANCE AND ESTIMATE RELEASES FROM EACH SOURCE
ANALYZE ENVIRONMENTAL TRANSPORT, TRANSFORMATION, AND FATE
(SECTION 5)
ESTIMATE CONCENTRATIONS IN WORKPLACE
WORKPLACE PERSONAL/BREATHING ZONE
(SECTION 7)
EXPOSURE CALCULATION
DETERMINE EXPOSED SKIN AREA, BREATHING RATE, INGESTION RATE
EVALUATE USE AND EFFICACY OF PROTECTIVE MEASURES
CALCULATE EXPOSURE FOR EACH WORKER POPULATION
(SECTION 6)
EXPOSED POPULATIONS ANALYSIS
IDENTIFY AND EVALUATE WORKER ACTIVITIES
ENUMERATE WORKERS IN ACTIVITIES
CHARACTERIZE WORKERS IN ACTIVITIES

Figure 1-1. Framework For Occupational Exposure Assessment

assessor can develop an exposure estimate by progressing through the full sequence of analyses indicated in the figure. For each source of exposure (or source category), a materials balance should be developed to determine all sources of release of the chemical to the workplace environment and to estimate the level of release from each source. In addition, any chemical or physical processes that may affect the chemical once it is released should be considered in order to determine its potential for transport or transformation within the workplace.

The results of these two analyses, quantification of the level of chemical release and determination of the chemical's fate within the workplace following release, provide a basis for estimating concentrations of the chemical within specified media in the workplace. These estimates of contaminant concentrations can then be used in conjunction with data quantifying worker inhalation rates, ingestion rates, and affected skin surface areas to estimate the degree of potential exposure.

The worker activity analysis step is useful in determining the amount of air inhaled, contaminant ingested, or chemical contacted by the skin; such factors are highly dependent on both the length of time the worker spends in a contaminated area and the type of activity that he or she is performing. Occupational exposure assessments also consider the effect of protective measures used specifically to limit or reduce worker exposure. Any protective measures (equipment and/or clothing) should be identified and their expected degree of effectiveness quantified. This information allows the assessor to adjust the exposure values to estimate the actual level of exposure incurred by workers using such measures.

The activity analysis identifies those categories of workers that are exposed as a result of each specific activity. This information directly identifies exposed worker subpopulations. Once identified, each exposed subpopulation is then enumerated, or counted, to determine the number of workers experiencing exposure in each activity category. The exposed worker populations are also characterized by age and sex in order to provide such additional information as susceptibility to specific toxic effects of certain classes of substances (e.g., mutagens or teratogens with respect to pre- versus post-menopausal working women), inhalation rates, and skin surface area available for contact. Such determinations will actually be executed in conjunction with the calculation of exposure. Population characterization also identifies subpopulations that may experience a greater risk from a given level of exposure than the population at large, because of the toxicity characteristics of the contaminants.

In some cases, workplace monitoring data or personal/breathing zone monitoring data may be available for the chemical(s) and occupational situations being assessed (see Section 3). In such cases, the assessment process described above can be significantly streamlined, as is illustrated in Figure 1-1. As the name suggests, workplace monitoring measures the ambient concentration of contaminants at particular locations in the workplace. Personal or breathing zone monitoring provides a more direct determination of contaminant concentrations to which individual workers are exposed than does workplace monitoring. Therefore, if such data are available and determined to be of acceptable quality, they can replace estimated concentrations that are based on a materials balance and fate analysis. It is important to note that monitoring data can be used in conjunction with estimates of exposure that are based on source strength when an exposure reduction/control options analysis is conducted.

The analytical framework described above can be applied to assessment of exposure to existing chemicals as well as to new chemicals (such as those evaluated by EPA in the Premanufacturing Notice, or PMN, assessment process). For existing chemicals, monitoring data may be available, thereby allowing a more direct analysis. Monitoring data will not be available for some new chemicals.

1.3 Organization of the Report

As indicated in Figure 1-1, the remaining sections of this report address specific components of the occupational exposure assessment process. Following this Introduction, Section 2 addresses determination of sources of occupational exposure. The acquisition, application, and limitations of monitoring data pertinent to occupational exposure assessments are discussed in Section 3. Section 4 describes the estimation of contaminant releases to the workplace and the development of a source mass balance. In Section 5, contaminant transport and transformation processes that may affect the fate of chemicals released to the occupational environment are described, and means of calculating (estimating) workplace contaminant concentrations resulting from estimated releases are detailed. Section 6 deals with the identification, enumeration, and characterization of exposed worker populations, and Section 7 addresses calculation of the level of exposure experienced by workers. References used in developing this document are presented in Section 8, which is followed by two appendices. Appendix A provides information on certain processes and industries, including details on the organic chemicals, lubricants, and plastics manufacturing industries. Appendix B is a general data source reference covering a broad range of information sources useful in conducting occupational exposure assessments.

2. SOURCES

Characterization of sources is a key step in performing an occupational exposure assessment. Source information includes the amount of the chemical produced, its products, where and how it is produced and used, and the releases of the chemical from production, transportation, use, and disposal. In this report, the source analysis has been divided into two separate sections. This section discusses only the amount of the chemical produced, its products, and where and how it is produced and used. The intention of this section is to serve as an organizing tool for the gathering and analysis of monitoring data (information on monitoring data is presented in Section 3). Section 4 discusses the generation of release estimates, which are necessary to estimate concentrations if monitoring data are not available.

The sources of exposure to a chemical in the occupational environment are manufacturing, processing, trade, commercial use, transportation, and disposal. Manufacturing includes not only modifying raw materials to produce an intermediate or finished product but also the mining (extraction) of raw materials (e.g., iron ore). Processing is the modification of a chemical or material from manufacturing to other products; processing may involve several industries. Trade is the distribution of products to commercial concerns or consumers. Commercial use is the application of chemicals or products in a commercial or business setting.

In the occupational setting, the two most important routes of entry of chemicals into the body are inhalation and chemical contact with skin (dermal exposure). Although the gastrointestinal tract is a potential site of absorption, the direct ingestion of significant amounts of chemicals is rare in occupational situations (Proctor and Hughes 1978). The sources section in this document, therefore, emphasizes the potential sources of the toxic chemical for inhalation and dermal exposures. It should be noted, however, that although relatively minor in magnitude compared with inhalation or dermal exposure, gastrointestinal exposure can indirectly occur in occupational settings as a result of inhalation of contaminant particles that are too large to penetrate to the alveoli in the lung. Such particles are removed from the respiratory system by ciliary movement of the mucous in which they become trapped. This contaminated mucous is then either eliminated from the body via expectoration or swallowed. In the latter case, such contaminants do become a gastrointestinal exposure problem. If the toxicological properties of a given chemical differ depending on whether the chemical is inhaled or ingested, distinguishing the degree of exposure via each route is critical to conducting an adequate exposure assessment. Section 7 of this report addresses means of calculating exposure to contaminants ingested either directly or indirectly.

In general, there are two broad categories of occupational releases, both of which are very closely tied to worker activities and exposure. These categories are direct releases and indirect releases. Direct releases are emissions that result in direct exposure to workers involved in activites that cause the release. Examples include releases associated with such activities as maintenance, cleanup, or sampling. Indirect releases are emissions that result in indirect exposure to workers, such as process vent, fugitive, and storage emissions. For example, a worker standing near a pumping operation can be indirectly exposed to emissions from a leaking pump seal.

Examination of the sources of a chemical substance in the occupational environment requires the following major steps:

- Determine manufacturing, processing, and use sites.
- Identify manufacturing, processing, and use processes.
- Characterize worker activities.
- Estimate releases.
- Characterize the substance at the release point.

Characterizing worker activities is briefly discussed in this section; it is discussed in detail in Section 4. Release estimates and the characterization of the substance at the release point are also discussed in Section 4. The remaining two steps are discussed below in subsections 2.1 and 2.2.

To perform each of the above steps, assessors acquire information from the following general sources: direct measurements, review articles, encyclopedias, scientific journal articles, basic research reports, government publications, computerized bibliographic systems and other guides to the published literature, EPA offices and other federal agencies, state or international organizations, custodians of unpublished materials (especially industry contacts), and guides to research in progress. The data sources applicable to the first two steps listed are discussed in the following sections along with guidance on how they are used.

The first step of this exposure assessment method is to review readily accessible information on the chemical. Some references are suggested in Table 2-1; notice that these are mostly encyclopedias which provide a general overview. Information that should be obtained in this step includes the type of chemical, its physical state at ambient conditions, the production volume, manufacturing (or mining) methods, and the chemical's uses. If the chemical is a PMN chemical, this information should be obtained from the Premanufacturing Notice or an analysis of surrogates.

Table 2-1. References Used to Obtain a General Overview of Chemical Manufacture[a]

Title	Author/Date
Encyclopedia of Chemical Technology (24 volumes)	Kirk-Othmer 1978-1984[b], third edition[c]
Chemical Process Industries	Shreve 1967
Chemical and Process Technology Encyclopedia	Considine 1974[c]
Faith, Keyes, and Clark Industrial Chemicals	Lowenheim & Moran 1975
Riegel's Handbook of Industrial Chemistry	Kent 1974
Encyclopedia of Polymer Science and Technology (16 volumes)	Gaylord and Mark 1964-1976[b,c]
Modern Plastics Encyclopedia	Agranoff 1980[c]
Pesticide Manufacturing and Toxic Materials Control Encyclopedia	Sittig 1980[c]
Mineral Commodity Profiles	Bureau of Mines 1980 (Annual Publication)

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[a] The choice of which references to examine first can be decided in part by the titles; the first five references are for general chemicals while the last four references are for special products or substances.

[b] Individual volumes in the series are published separately.

[c] Revised or updated editions of these publications should be consulted as they become available.

2.1 Determining Chemical Manufacturing, Processing, and Use Locations

Geographic location information aids in the identification of applicable monitoring and population data; such site specific data are usually the best available for use in occupational exposure assessments. Volume 1 of this report series (Methods for Assessing Exposure to Chemical Substances: Introduction; Versar 1985a) details the information sources to be used in this evaluation.

2.2 Identifying Production and Use Processes and Activities

2.2.1 Manufacturing

(1) Examining Manufacturing Processes. In general, processes used to synthesize the chemical include manufacturing processes or mining and beneficiation operations. The unit processes used in the manufacture of major organic chemicals and lubricants are listed in Table 2-2 and discussed in Appendix A. Usually more than one direct synthesis route exists. For example, there are two synthesis routes for the production of cyclohexane: catalytic hydrogenation of benzene, which accounts for approximately 85 percent of the cyclohexane capacity in the United States, and separation from petroleum liquids, which constitutes the remaining 15 percent (ITE 1980). All synthesis routes must be analyzed because each route has a different exposure potential.

Table 2-3 presents references for information on synthesis routes. The first two sources of information are usually sufficient to find the synthesis routes for existing chemicals. The other sources of information on this table are used primarily to construct the process flow diagrams for use in process mass balance development (see Section 4). The assessor should check to see whether the chemical or its industry has been reviewed by the government agencies mentioned in part 2 of Table 2-3, especially the U.S. Environmental Protection Agency. Such publications will generally present process flow diagrams. If the chemical is a new substance or a low volume production chemical, such as a dye or a pigment, the process flow diagram may be unavailable in the literature. In that case, a specialty literature search (i.e., review of files that are not normally searched) will be necessary. An example would be checking the patent files, which often contain process information with diagrams. The information from different sources may not be totally consistent; this is usually because process variations occur within synthesis routes from process to process.

The process flow diagram shows points of potential release and exposure: locations of vents, valves, and pumps; points at which water contacts the process stream; and operations, such as grinding, that may

Table 2-2. Unit Processes Used in the Manufacture of Organic Chemicals

Alkylation
Amination by ammonolysis
Ammoxidation
Carbonylation (oxo)
Condensation
Cracking (catalytic)
Dehydration
Dehydrogenation
Dehydrohalogenation
Esterification
Halogenation
Hydrodealkylation
Hydrogenation
Hydrolysis (hydration)
Nitration
Oxidation
Oxyhalogenation
Phosgenation
Polymerization
Pyrolysis
Reforming
Sulfonation

Table 2-3. Information Resources for Synthesis Routes and Their Flow Diagrams

Sources of information	Data provided: Lists different synthesis routes	Data provided: Provides process flow diagrams	Comments
I. References for major chemicals			
Chemical Economics Handbook (SRI 1980)[a]	x	x	Very good source.
Chemical and Process Technology Encyclopedia (Considine 1974)[a]	x	x	Very good source for process descriptons.
Encyclopedia of Chemical Technology (Kirk-Othmer 1978-1984)[a]	x	x	Good source for general chemical overviews.
Chemical Process Industries (Shreve 1967)[a]	x	x	Good source for process descriptions.
Encyclopedia of Polymer Science and Technology (Gaylord and Mark 1964-1976)	x	x	Very good source for polymer process descriptions.
Modern Plastics Encyclopedia (Agranoff 1980)	x	x	Very good source for polymer process descriptions.
Organic Chemical Manufacturing (ITE 1980)	x	x	Excellent source for the organic chemicals that are reviewed.
Kline Guides - Industrial Marketing (Kline 1977a and b; 1978a and b; 1980)	x	x	Good references for chemical, paper, plastics, paint, and packaging industries.
Faith, Keyes and Clark - Industrial Chemistry (Lowenhelm and Moran 1975)[a]	x	x	Major synthesis routes discussed; lists other routes.
Unit Process Guide to Organic Chemical Industries (Herrick et al. 1979)	x		Only lists reactions for major chemicals.
Organic Chemical Producers Data Base (Radian 1979)	x		Lists synthesis routes.

Table 2-3. (Continued)

Sources of information	Data provided		Comments
	Lists different synthesis routes	Provides process flow diagrams	
MEDLARS/TDB Toxicology Data Bank	x		Lists synthesis routes.
Reigel's Handbook of Industrial Chemicals (Kent 1974)	x		Some process descriptions. Discusses wastewater treatment and air pollution control technology.
U.S. Petrochemicals, Technologies, Markets, and Economics (Brownstein 1972)[a]	x	x	Only discusses petrochemicals.
Chemical Product Synopsis (Mannsville Chemical Products (1976)	x		Only lists synthesis routes.
Chemical Marketing Journals (magazines)[a]	x	x	Must search for appropriate issue.
Industrial Minerals and Rocks (American Institute of Mining, Metallurgical and Petroleum Engineers, Inc. 1975)	x	x	Very good source for mining industry.
Industrial Minerals (journal)	x	x	Articles will provide process descriptions.
Mineral Commodity Profiles (Bureau of Mines 1981)	x	x	Describes mining techniques used for various chemicals.
Minerals Yearbook (Bureau of Mines 1981)	x	x	Describes mining techniques used for various chemicals.
Methodology for Material Balance (Slimak et al. 1982)			Lists other references that may be useful.

Table 2-3. (Continued)

Sources of information	Data provided Lists different synthesis routes	Provides process flow diagrams	Comments
II. Government agencies - general publications			
USEPA - Office of Toxic Substances(a) Office of Air Quality Planning and Standards Office of Water and Waste Management Office of Solid Waste	x	x	If a document has been written on the chemical or its industry, it will generally have process descriptions. The Development Documents for air and water standards are good references.
Dept. of HEW; NIOSH(a)	x	x	Control technology assessments for industries are useful. They describe industrial exposure.
Dept. of Labor; OSHA(a)	x	x	Documents on industry have descriptions of occupational exposure.
Dept. of the Interior; Bureau of Mines(a)	x	x	Documents on minerals.
III. Speciality literature search on DIALOG			
Patent files(a)		x	Discusses process and chemical.
Chemical abstracts(a)	x	x	Discusses process and chemical.
IV. Industry public relations material(a)			
Examples of company brochures: Polystyrene (Amoco Chemicals Corporation 1980) Polypropylene (Amoco Chemicals Corporation 1980)	x	x	Company brochures on chemicals and/or processes are useful in confirming information from other sources.

(a) These sources address a variety of industries.

release particulates. The physical state of emissions is an important determinant affecting exposure.

It should be known at this point whether the plant is indoors or outdoors, whether the process is batch or continuous, whether the system is open or closed, and whether the transfers are manual or mechanical. Each of these parameters to some degree determine the potential for occupational exposure.

2.2.2 Processing

Processing industries are those industries that use the product from manufacturing and further process, modify, or fabricate it to produce either another intermediate product (to be further processed or fabricated into a finished product by other processing industries) or a finished product. Table 2-4 lists some of the processes characterized in Appendix A-4. Several steps may be involved in manufacturing a finished product. For example, production of a resin product might involve the following five manufacturing and processing steps: organic chemical manufacturing, resin formulation, resin compounding, resin molding, and resin decorating.

There are two categories of uses: consumptive and nonconsumptive. A consumptive use occurs when the chemical undergoes a chemical reaction to form a new chemical. Nonconsumptive uses are those where the chemical does not react but remains intact, e.g., as a solvent, a deodorizer, or a pesticide (JRB 1980). Generally, subsequent processing involving a chemical that is used consumptively should be examined by the assessor if leaching or off-gassing of residual, unreacted chemical is likely, or if degradation of the new chemical to form the original chemical is suspected. Examples are leaching of residual vinyl chloride monomers from polyvinyl chloride pipes or formaldehyde off-gassing from particleboards due to hydrolytic degradation of urea-formaldehyde resins used as wood binders. If it is known that no additional releases of the given chemical will occur from such uses, then no additional analysis is necessary. All nonconsumptive uses must be examined up to and including disposal.

The uses of the chemical should be determined in order to identify the type of processing that occurs after it is produced. For most major chemicals, the references listed in Tables 2-1 and 2-3 should provide that information. However, a specialty literature search (usually via on-line computerized literature review systems such as DIALOG or ORBIT) may be needed to find obscure uses and to verify the uses found in the references. Product formulations are usually trade secrets; as a result, determining uses and corresponding amounts is extremely difficult.

Table 2-4. Operations Used in Processing Industries and Characteristic Types of Releases

Process types	Contaminant type categories	Contaminant examples (type)
Hot operations		
Welding	Gases (g)	Chromates (p)
Chemical reactions	Particulates (p)	Zinc and compounds (p)
Soldering	(dust, fumes, mists)	Manganese and compounds (p)
Melting		Metal oxides (p)
Modling		Carbon monoxide (g)
Burning		Ozone (g)
		Cadmium oxide (p)
		Fluorides (p)
		Lead (p)
		Vinyl chloride (g)
Liquid operations		
Painting	Vapors (v)	Benzene (v)
Degreasing	Gases (g)	Trichloroethylene (v)
Dipping	Mists (m)	Methylene chloride (v)
Spraying		1,1,1-Trichloroethane (v)
Brushing		Hydrochloric acid (m)
Coating		Sulfuric acid (m)
Etching		Hydrogen chloride (g)
Cleaning		Cyanide salts (m)
Dry cleaning		Chromic acid (m)
Pickling		Hydrogen cyanide (g)
Plating		TDI, MDI (v)
Mixing		Hydrogen sulfide (g)
Galvanizing		Sulfur dioxide (g)
Chemical reactions		Carbon tetrachloride (v)
Solid operations		
Pouring	Particulates	Cement
Mixing		Quartz (free silica)
Separations		Fibrous glass
Extraction		
Crushing		
Conveying		
Loading		
Bagging		

Table 2-4. (Continued)

Process Types	Contaminant type categories	Contaminant examples (type)
Pressurized spraying		
Cleaning parts	Vapors (v)	Organic solvents (v)
Applying pesticides	Dusts (d)	Chlordane (m)
Degreasing	Mists (m)	Parathion (m)
Sand blasting		Trichloroethylene (v)
Painting		1,1,1-trichloroethane (v)
		Methylene chloride (v)
		Quartz (free silica) (d)
Shaping operations		
Cutting	Dusts	Asbestos
Grinding		Berylium
Filing		Uranium
Milling		Zinc
Molding		Lead
Sawing		

Source: Olishifski et al. 1979.

After a substance's uses are identified, the relevant processes should be described. The processes employed in the conversion of the products of manufacturing to other products are numerous. Appendix A-2, Table 25, and Appendix A-4, list and characterize the processes used in the manufacture of plastics as well as some general manufacturing steps. Table 2-5 lists some unit operations with indirect process releases that have a high potential for exposing workers in the manufacturing industries.

2.2.3 General Industrial Worker Activities

It is important for exposure assessors to be familiar with general industrial worker activities as an aid in the selection of monitoring data; detailed information on the relationship between worker activities and releases is presented in Section 4.

The general worker activities associated with industrial operations (manufacturing and processing) include the following:

1. Drumming of Liquids - Liquids are drained into a drum by either splash loading or subsurface loading. Splash loading is used for most applications and typically leads to more emissions than subsurface loading.

2. Drumming and Bagging of Solids - This operation can be either manual or automated. Automated systems are only economical for larger operations; they significantly reduce worker exposure.

3. Cleaning of Process Equipment - Cleaning of process equipment involves the removal of residual material from such equipment as storage tanks, holding tanks, stills, reaction vessels, and pipework. Although this is generally a short-term activity, it may result in significant levels of exposure.

4. Maintenance - Maintenance involves the mechanical adjustment, alteration, repair, or replacement of process equipment. These operations may be performed from outside of the process equipment, through openings, or from within the equipment.

5. Sampling and Analysis - Sampling and analysis operations are used to check the quality of products and intermediates and to check for material losses. A broad range of potential worker exposure is possible because of the diverse procedures used during sampling and analysis.

6. Supervising Equipment Operations - In manufacturing and processing operations, engineers and technicians are needed to monitor and control equipment. In most plants, process controls

Table 2-5. Specific Operations That Require Hoods and May Lead to Occupational Exposure from Indirect Process Releases

Group	Operation	Group	Operation
1. Foundry	Abrasive blasting	4. Painting	Spray painting
	Core grinding		Oven drying
	Furnace melting		
	Mixing and mulling	5. Wood working	Joining
	Pouring		Sanding
	Shakeout		Planing
	Tumbling		Surfacing
	Shell core molding		Molding
	Die casting		Matching
	Calender rolling		Sizing
2. Material handling	Bag filling and opening	6. Metal working	Buffing and polishing
	Barrel filling		Grinding
	Bin and hopper loading		Spraying
	Bucket elevator operation		Welding
	Conveyor belt operation		Cutting
	Screening		Chipping
3. Open-tank operations	Solvent degreasing		Soldering
	Anodizing		
	Dipping		
	Metal cleaning		
	Stripping		
	Pickling		
	Molten salt batch treatment		
	Bonderizing		
	Descaling		
	Hard coating		
	Parkerizing		
	Etching		
	Plating		
	Electropolishing		

Table 2-5. (Continued)

Group	Operation
7. Asbestos products manufacture	Carding
	Crushing
	Drilling
	Grinding
	Pressing
	Screening
	Spool winding
	Spinning
	Twisting
	Weaving
8. Miscellaneous	Wire brushing
	Lathing
	Outboard motor testing
	Grain storage and milling
	Quartz fusing
	Wire impregnating
	Laboratory bench work

Source: Committee on Industrial Ventilation 1980.

and monitors are automated and separated from the actual equipment. In more manually operated plants, equipment is generally situated to minimize direct worker exposure. Consequently, only indirect exposure should occur from equipment supervision.

At this point, the exposure assessor should have a general knowledge of the manufacturing and processing operations and worker activities associated with the chemical of concern; this will be helpful in locating monitoring data (see Section 3). If monitoring data are not available, this information will provide a starting point for estimating releases from manufacturing and processing operations (see Section 4).

2.2.4 Activities of Wholesale and Retail Trade

The activities of workers in wholesale and retail trade can be grouped in six classes: loading, storage, packaging, shelving, demonstration, and sales. The activities may be sources of occupational exposure in three possible ways:

- Accidental loss of product through package failure (e.g., loading, storage, shelving).
- Lack of packaging or insufficient containerization of product with resultant atmospheric emissions (e.g., loading, storage).
- Direct contact with a product (e.g., loading, packaging, demonstration).

The relationship between the activities of wholesale and retail trade are explained in more detail in Section 4.

The activities of commercial use include most workplace situations outside manufacturing and trade; this sector is dominated by the service industries. The activities of this use category are not listed here because they are so numerous and diverse; more information on these activities is presented in Section 4.

3. MONITORING DATA

The assessment of exposure to a chemical substance should quantitatively describe the level, duration, and frequency of human contact with the substance, as well as the route of such exposure. Quantitative estimates of exposure are generally based on monitoring data or simulation models.

Where sufficient monitoring data exist, it may be possible to trace the pathway of a substance from the point at which exposure occurs to its source. Limited monitoring data are also useful. They can indicate the quantity of a chemical at a particular location, at a specific point in time. They can also be used to evaluate the validity of model-generated estimates.

To be properly utilized, monitoring data must be placed in perspective as to their validity. Even in situations where some data have already been collected, supplemental data will often be necessary because certain deficiencies in existing data will limit applicability and reliability. Quality assurance/quality control measures used may be unknown or inadequate. Data may be obsolete because of changes in operating conditions or control technologies. Therefore, before using monitoring data, the assessor should ask the following questions:

- Are the data representative of current normal conditions, or do they reflect obsolete conditions or temporary aberrations resulting in high or low concentrations?
- Are the data accurate and precise? Were sampling and measurements performed in the most appropriate manner?
- Does the sampling design result in statistically valid data?
- Where was the monitoring device located with respect to the source(s)?

Data quality is a function of the accuracy, precision, representativeness, comparability, and completeness of the data collected. In general, data quality requirements (in terms of defensibility of the results obtained) in monitoring studies usually increase according to the intended data use in the following sequence: (1) screening studies to determine the presence or absence of pollutants; (2) quantitative studies to determine concentrations of pollutants for source characterization, analysis of environmental fate, and exposure assessment; (3) quantitative studies to determine concentrations of pollutants for use in development of control strategies; and (4) quantitative studies to determine concentrations for the purpose of supporting enforcement actions. It should be noted, however, that this hierarchy does not necessarily apply to the quantification level required by these four use categories. For example, enforcement monitoring may only require quantification of values over an action level, and the data generated in such cases may thus not be detailed enough to support a detailed exposure assessment.

Data quality aspects pertinent to the use of monitoring data in occupational exposure assessment are discussed below in Section 3.1. In addition, the type of monitoring conducted and the sample collection techniques used also have a significant effect on how monitoring data are interpreted and exposure is measured. Section 3.2 discusses the types of monitoring used in the workplace; the following section (3.3) describes commonly used sample collection techniques. Exposure measurement strategies are delineated in Section 3.4, and Section 3.5 summarizes readily available occupational monitoring data sources.

3.1 QA/QC Considerations

Whether newly generated data or existing data are used in an occupational exposure assessment, the data must meet the quality criteria dictated by their proposed use. In the case of new data, satisfying quality requirements may be a rather straightforward undertaking. Data quality goals in terms of precision and accuracy can be achieved by adhering to a well-structured monitoring program designed from a statistically sound sampling plan. Quality standards are prescribed in relation to the research questions and study objectives; monitoring activities are then organized and planned to ensure that these standards are met. Detailed guidance for implementing QA/QC procedures in the design and conduct of monitoring studies can be obtained from USEPA 1980a and USEPA 1980b.

Each of the potential data quality problems listed above should be addressed before available data are applied to an occupational exposure assessment. Evaluation guidelines to help determine the relative significance of each of these problem issues are presented in this section. Existing data sets should be evaluated against these guidelines, which pertain to:

- Sample design.
- Sample collection activities in the field.
- Data entry and processing.

The major consideration in evaluating existing monitoring data is the motivating factor or objective for which the data were generated. To address this consideration, this section assumes that documentation for the data sets being evaluated is available; that information relevant to each major component of the study in which the data was developed can be extracted; and that a QA/QC plan adequate to resolve any question of data quality is available. Without the appropriate documentation, a discussion of existing data evaluation is futile, and the use of such data will, at best, be limited.

3.1.1 Sample Design

This component requires an evaluation of the data's applicability to the physical problem (research question) under investigation and the appropriateness of the collection/measurement systems or processes used. The following questions should be answered:

- What were the specific research objectives for which answers were sought through data development?
- Did the parameters monitored reflect the research objectives?
- Did the media in which the parameters were monitored reflect the research objectives?
- Were the sampling methods proposed suitable for the media and parameters monitored?
- Were QC elements such as inter-lab analyses and peer review of analyses results incorporated into the design?
- Did the study attempt to correlate source and pathway monitoring activities?
- Were sampling frequency and duration adequate and representative of the conditions surrounding the research objectives?
- Was allowable survey error specified?

3.1.2 Sample Collection

Adherence to established protocols during sample collection should be determined. The following questions should be answered:

- Were standard operating procedures employed?
- Were established sample collection, preservation, storage, and transport protocols used?
- Were control, blank, and spiked samples provided?
- Were replicate samples provided?

3.1.3 Analytical Measurement Systems

The laboratory procedures through which monitoring samples were analyzed must be evaluated for adherence to established protocols. Specific questions that should be answered are:

- Were proper protocols used in the analysis of samples?
- Were standard operating procedures used?
- Were issues surrounding the limits of detection addressed?
- Were positives confirmed by other means of analysis?
- Were instruments calibrated accurately?
- Were results of blank, control, spiked, and replicate sample analyses maintained?
- Were precision and accuracy determinations documented?

3.1.4 Data Entry and Processing

Evaluations of the data entry and processing aspects of the existing data as well as of data documentation and review should be conducted. Significant questions in this portion of the evaluation include:

- Were data entry QC checks performed?
- Does the number of significant figures presented in the data set correspond to the observed variance of the measurements?
- Were confidence interval estimates made?
- Was sampling program documentation given peer review? Are results available?
- Was an estimate of total sampling measurement error made?

From a pragmatic standpoint, it is likely that existing data will often not meet the current QA/QC requirements for development of new data. In such cases, the assessor should exercise extreme caution and considerable professional judgement in deciding to what extent (and for what purpose) the data can be used.

3.2 Types of Monitoring

Occupational exposure can occur from manufacturing, transportation, storage, processing, disposal, or industrial use of a chemical substance or a material containing that substance. To determine exposure from a chemical substance, two categories of air monitoring are generally used: personal/breathing zone monitoring and workplace monitoring (area monitoring or environmental surveillance). Biological contaminant body burden monitoring is a third type of occupational exposure monitoring.

3.2.1 Personal/Breathing Zone Monitoring

Personal monitoring is the measurement of an employee's exposure to airborne contaminants by a device worn by the person being sampled and placed as close to the contaminant's route of entry to the human body as possible. In breathing zone monitoring, a second person holds the sampling device in the breathing zone of the person being sampled.

3.2.2 Workplace or Area Monitoring

Occupational environmental monitoring is the measurement of contaminant concentrations in the workplace (which may or may not be enclosed); measurement devices are placed close to the worker's normal work area. Samplers are usually stationary and may remain in place for an extended period of time.

3.2.3 Biological Monitoring

Biological measurements usually determine the concentration of a specific agent in the blood, adipose tissue, or urine, although samples of other biological material such as hair or nails may also be useful. Such measurements represent the body burden of that agent and can be used as a monitor of the worker's exposure to a specific substance. Biological levels of a substance will indicate the combined level of worker exposure; they can be used to assess where excessive exposures have occurred and when protection from further exposure is necessary (Piotrowski 1977).

There is currently no straightforward way to relate body burden to exposure, although work is underway to identify and quantify such relationships. There is similarly no method to determine the pathway from which each increment of exposure, measured by body burden, was derived. Biological measurements are best used at present as a qualitative indicator that exposure has occurred.

3.3 Sample Collection Techniques

The Occupational Safety and Health Administration (OSHA) health regulations require that an employee's exposure be measured by any combination of long-term or short-term samples that represent the employee's actual exposure.

The National Institute for Occupational Safety and Health (NIOSH) Manual of Sampling Data Sheets and its supplement describe sampling methods for nearly 30 substances. It is the only available compendium of such methods. Most of these methods have been recommended to OSHA for use in their compliance program. Except for a few compounds, occupational exposure to these 30 substances is regulated by 29 CFR, Part 1910.

3.3.1 Types of Samples

As mentioned above, the three basic types of occupational environmental sample collection techniques are personal/breathing zone, general area, and biological samples:

1. Personal/breathing zone - in personal monitoring, the sampling device (a dosimeter) is directly attached to the employee (clipped to the worker's collar or lapel, for example), who wears it continuously during all work and rest operations. To obtain breathing zone samples, the sampling device is simply held at the "breathing zone" of the employee; the "breathing zone" is that air that would most likely be inhaled by that employee.

2. General area ("general air") - the sampler is placed in a fixed location in the work area generally occupied by employees.

3. Biological samples - For occupational body burden monitoring studies, breath, urine, and hair samples can be collected fairly easily and without excessive imposition on the persons sampled. A subject's exhaled breath can be collected by a portable spirometer, and the samples analyzed in the same fashion as other air samples. Other possible body burden samples that can be useful in occupational exposure assessments include blood and, where lactating mothers are involved, mother's milk. However, obtaining such samples is considerably more invasive than is the case for the sample types addressed above. Therefore, such data may only be generated in occupational exposure verification studies or for assessment of exposure to especially high risk contaminants.

For the determination of employee exposure, it is preferable to use exposure data obtained by the personal or breathing zone methods; these are direct methods. If exposure data obtained by the less direct "general air" method are used, an analysis to determine how accurately the general air data represent employee exposures should be included. This may be accomplished by comparison between general air and personal or breathing zone samples to demonstrate equivalency, which is very difficult (Leidel et al. 1977). If this analysis of equivalency is not included, use of "general air" data for exposure assessment may make the estimates inaccurate enough to allow only a screening level assessment to be made.

3.3.2 Employees Sampled

Occupational monitoring data are often collected by OSHA or by employers using OSHA's guidelines. Among those guidelines are recommendations regarding which employees should be monitored. A less-than-random choice in sampling strategy may introduce biases in the resultant data that must be taken into account in an exposure assessment.

The following three categories of employee sampling are required by OSHA:

(1) Maximum risk employee. Once exposure above the action level has been identified, OSHA requires that employers sample the "maximum risk employee." Generally, the employee closest to the source of hazardous material is selected to be at maximum risk. OSHA suggests that employee mobility and work habits and air movement patterns be considered as well (Leidel et al. 1977). These factors are difficult to evaluate and may be neglected by most exposure samplers.

Monitoring data based on the maximum risk employees' exposure will be skewed to the high end of the range of concentrations in the workplace. It may be difficult to ascertain that the data were based on the maximum risk employee. If such a determination is possible, it should be stated that the exposure approximates worst-case conditions.

(2) Random sampling of a group of workers. If a maximum risk worker is not identified for a given operation, random sampling of a group of workers is performed. The objective of the method is to select a subgroup of adequate size; the probability that the random sample will contain at least one worker with high exposure will then be high. This procedure is carried out by (1) determining the number of employees to be sampled, then (2) randomly selecting the employees to be sampled (Leidel et al. 1977). Data collected in this manner are fairly representative of conditions throughout the workplace.

(3) Sampling for periodic exposure. OSHA recognizes that infrequent exposure to toxic substances may occur during operations such as process/product sampling or cleaning. Employers are required to sample during those activities if they believe that significant exposures are likely to occur. It may not be possible to distinguish such data from other OSHA data.

3.4 Exposure Measurement Strategies

Although there is no "best" strategy applicable to all occupational situations, some strategies are clearly better than others. Guidelines are presented in this section to aid assessors in comparing data obtained via alternative strategies.

The accuracy required of airborne concentration measurements in the OSHA health standards considers (Leidel et al. 1977):

1. The random variations in the sampling device (repeatability of the sampling device).
2. Random variations in the analytical procedure (repeatability of the replicate analyses of a given sample).
3. Systematic errors in the sampling method (determinate errors or bias in the collection technique).
4. Systematic errors in the analytical procedure (determinate errors or bias in the analysis).

The term "accuracy" refers to the difference between a measured concentration and the true concentration of the sample. It includes both the random variation of the method (referred to as precision) and the difference between the average result from the method and the true value.

The accuracy of a sample collection method should generally have a statistically-determined confidence level of at least 90 percent. To gauge the accuracy of the sampling and analytical methods used in obtaining exposure measurements, the following evidence should be sought:

1. The use of NIOSH-certified detector tubes.
2. Field calibration procedures for sampling equipment.
3. The analysis of samples at a laboratory participating in an industrial hygiene quality control program, for example one conducted by American Industrial Hygiene Association.

Data collected under the auspices of NIOSH and OSHA can usually be easily evaluated for accuracy. Exposure concentrations are usually reported as 15-minute "ceiling standard" measurements or as an eight-hour time-weighted average. Each is defined and discussed in the following section.

3.4.1 Sample Measurement

Table 3-1 describes the four types of measurements taken to determine exposure. Grab samples are taken when it is impossible (due to limitations in measurement methods, e.g., direct reading meters or colorimetric detector tubes) to collect either a single sample or a series of consecutive samples whose total duration approximates the period for which the standard is defined.

3.4.2 Length and Duration of Measurement

(1) Time-weighted average (TWA). To determine the time-weighted average exposure of an employee, a detailed description of "where he is when" must be obtained. Typically, the employee may be exposed to several different short-term concentrations during a workshift due to changes in job assignment, workload, ventilation, and industrial processes. The TWA evolved as a method of calculating daily or full-shift average exposure by weighing the various short-term average concentrations. This method is the equivalent of integrating the concentration values over the total time base of the TWA, which can be determined by the following formula:

$$\frac{\sum_{i=1}^{i=r} (T_i) \cdot (C_i)}{T_{total}} = TWA \qquad \text{(Equation 3-1)}$$

where

T_i = Duration of incremental exposure.
C_i = Concentration of a specific air contaminant during the incremental time period Ti.
T_{total} = Total work time per shift; eight-hour workday.

Guidelines for comparing different exposure measurement strategies for the TWA standard are presented in Table 3-2.

Occupational exposure variation (intraday or interday) of specific work operations is practically impossible to predict. Intraday and interday variations, as measured by the geometric standard deviation (GSD), typically lie between 1.25 and 2.5 (Leidel et al. 1977, Ayer and

Table 3-1. Types of Measurement Samples To Be Obtained for Assessment of Occupational Exposure

Type of sample	Definition
Full period, single sample measurement	Sample taken for the full period of 8 hours for the 8-hour TWA standard and 15 minutes for a ceiling standard.
Full period, consecutive samples measurement	Several samples (equal or unequal time duration) obtained during entire period appropriate to the standard.
Partial period, consecutive samples measurement	One or several samples (equal or unequal time duration) obtained for only a portion of the period appropriate to the standard.
Grab samples measurement	A number of samples taken for short periods of time (less than 1 hour each and generally only minutes or seconds). Taken at random intervals over the period of time for which the standard is defined.

Source: Leidel et al. 1977

Table 3-2. Guidelines for Comparing an Eight-hour TWA Standard

Type of measurement	Basis for ranking (in order of decreasing desirability)
Full period, consecutive samples	Yields narrowest confidence limits on exposure estimate.
	Two consecutive, full period samples (about 4 hours each for an 8-hour TWA standard) provide sufficient precision and are recommended as the "best" measurement to make.
Full period, single sample (one 8-hour sample)	Appropriate sampling and analytical method must be available.
Partial period consecutive samples	Major problem is how to handle the unsampled portion of the period.
	In reality, the measurements are valid only for the duration of the period that the measurements cover (as 6 out of 8 hours).
	Professional judgment can be used to infer exposure during unsampled period. Knowledge of operations(s) is required.
	Sampled portion of period should cover at least 70-80 percent of the full period.
Grab sample	Confidence on exposure estimate is very low, and one has to have a low exposure average to statistically demonstrate compliance.
	Optimum number of samples to take is between 8 and 11 if employee's operation and work exposure are relatively constant during the day. If employee's operation and work exposure are not constant throughout the day, then at least 8 to 11 grab samples should be taken during each period of expected differing exposure.
	It is desirable to choose the sampling periods in a statistically random fashion.*

* Random sampling is sampling any portion of the work shift, each portion having the same chance of being sampled as any other.

Source: Leidel et al. 1977

Burg 1973). Exposure variation and the precision and accuracy of sampling and analytical methods were taken into consideration in developing the guidelines by Leidel et al. (1977) presented in Table 3-2.

(2) Strategy for a ceiling standard. Samples obtained for the determination of compliance with ceiling standards are treated in a manner similar to that used with samples taken for comparison with TWA standards. However, two important differences should be noted.

First, the samples obtained for comparison with ceiling standards are best taken in a nonrandom fashion. For example, available knowledge relating to the area, individual, and process being sampled should be used to obtain samples during periods of maximum expected concentrations of the substance.

Second, samples taken for comparison with ceiling standards are usually taken for a much shorter time period than those obtained for calculating TWAs. Measurements for ceiling standards should consist of 15-minute samples obtained in an employee's breathing zone; alternatively, consecutive samples totaling 15 minutes can be used. A minimum of three measurements should have been obtained during one work shift to provide a good estimation of the worker's exposure for that shift (Leidel et al. 1977).

3.5 Available Information on Occupational Exposure

It may be helpful to the exposure assessor to be aware of the various exposure limits and standards in effect when monitoring data are collected. For example, a recognized hazardous substance will be subject to an occupational exposure standard; knowledge that such a standard exists may lead to the identification of useful information that has been gathered by a public agency such as NIOSH. The following organizations are involved with occupational exposure standards:

- American Conference of Government Industrial Hygienists (ACGIH) - Can provide information on Threshold Limit Values (TLVs), industrial ventilation guidance, and air sampling and analysis instrumentation. Background information and the rationale underlying the TLVs are also available.
- American National Standards Institute (ANSI) - Can provide industry voluntary health and safety standards (as contrasted against governmental mandatory standards). Background information and underlying rationale for such standards may be available in some cases.

- American Industrial Hygiene Association (AIHA) - Develops Hygienic Guides for specific chemicals. These contain chemical and physical property information, summaries of chemical toxicity testing, summaries of recommended standards (NIOSH, etc.), and reference sources for this information.

- National Institute for Occupational Safety and Health (NIOSH).

- Occupational Safety and Health Administration (OSHA).

Readily available data from NIOSH and OSHA are summarized in the following sections.

3.5.1 National Institute of Occupational Safety and Health

Much information has been collected by NIOSH concerning employee exposure to chemical substances. Of most importance are:

1. Various reports dealing with exposure to substances in specific work settings. These include Health Hazard Evaluation Reports, Industrywide Studies, and Control Technology Assessments. These reports are prepared by NIOSH and its contractors and include actual sampling and analysis data gathered in the workplace. In order to most efficiently determine what documentation is available through NIOSH concerning given occupational exposure situations (chemical-specific, plant-specific, industry-specific), the assessor should contact Mr. Rodger Tatken, NIOSH Technical Information Branch, Cincinnatti, Ohio, 513-684-8328.

   The Health Hazard Evaluation (HHE) reports are developed at the request of either employers or employees. They are based on information obtained by NIOSH through actual site visits. Companies know when NIOSH will conduct such inspections, and the reports reflect the conditions observed by NIOSH inspectors at the time of the visit.* They contain a range of plant-specific and chemical-specific information including a description of the plant and its workforce, an identification of the products produced, description of the health and safety program in force at the plant, toxicological information for the chemical(s) under evaluation, the sampling and analytical methods used and analytical results obtained, and conclusions and recommendations.†

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*Personal communication between James (Jay) Jones, NIOSH, and L. Schultz, Versar Inc., November 28, 1984.

†Personal communication between Thomas Bloom, NIOSH, and L. Schultz, Versar Inc., November 28, 1984.

Industrywide Studies are primarily epidemiological studies of the effects of specific workplace chemicals throughout given industries. However, monitoring data generated by NIOSH in developing these reports are presented, as is any existing exposure incidence information generated by the industry under scrutiny.*

Control Technology Assessments are usually conducted on a process-specific or industry-specific basis, although occasionally chemical-specific reports are also generated. These studies evaluate the effectiveness of various types of exposure controls used in actual workplace settings. In developing these documents, NIOSH may conduct monitoring in the workplace to identify the best control technology for given situations. Process controls, equipment controls (ventilation, etc.), and work practices are all evaluated to varying degrees in these studies.

2. NIOSH Criteria Documents. Annually, about 24 criteria documents are produced. They cover single chemicals, classes of chemicals, physical agents, and industrial processes, and they recommend standards for occupational exposure. These documents, which are probably the single best source of information on occupational exposure, are in-depth reviews of information from the National Occupational Health Survey (NOHS - described below), other investigations carried out by NIOSH, and international scientific literature. They consider both published information and new research findings and sometimes reveal that a hazard is more severe than was initially thought.

3. The National Occupational Hazard Survey. This two-year field study, initiated in 1972, was intended to describe the health and safety conditions in the American work environment. A chief concern was the determination of the extent of worker exposure to chemical and physical agents. The survey involved the examination of 4,636 business establishments in 67 metropolitan areas selected by the Bureau of Labor Statistics as representative of the nonagricultural businesses covered by the Occupational Safety and Health Act of 1970. The survey identified approximately 8,000 chemical substances and physical agents as potential hazards. Data in the NOHS system can be accessed based on chemical name, product trade name, and generic product type to obtain quantitative output that includes the product formulation, the estimated number of plants wherein exposure occurs, and the estimated number of people experiencing the exposure. Output reports are aggregated to the national level based on the survey data. Also, although this data base contains data for over 72,000 products, the product formulation data for approximately 1/3 of these products are considered trade secrets by their producers, and therefore the formulation data cannot be released by NIOSH.

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*Personal communication between Thomas Bloom, NIOSH, and L. Schultz, Versar Inc., November 28, 1984.

Despite the fact that the NOHS data base has been useful for assessing occupational exposure to chemical substances, it has several characteristics that limit its usefulness. Because the data were collected over 10 years ago, some may be obsolete. Additionally, the data collection method relied to a large extent on the observations of a surveyor, who interviewed plant management and personnel and toured the plant, noting the number of employees potentially exposed to chemical substances. It is likely that some of the data reflect judgments by the surveyor, even though the survey procedures were designed to minimize subjectivity.

Furthermore, although over 4,500 different facilities were surveyed and data were extrapolated to a nationwide scale, certain types of facilities were excluded from the survey. Those excluded were (1) classified, because of national security, (2) engaged in agricultural production, (3) engaged in mining, other than oil or gas production, or (4) private households.

Finally, some of the chemicals evaluated by the survey may no longer be used or perhaps may be currently used at levels lower than those reported by the survey.*

Despite its limitations, the NOHS data base has been useful in the identification and quantification of occupationally exposed workers. A similar survey, termed the National Occupational Exposure Survey (NOES), was initiated in October 1980 with data collection beginning in November of that year. As of early 1985, data acquisition efforts for this survey had not been completed; NIOSH was still in the process of obtaining trade name product formulation data from the buisnesses surveyed. It is specifically this portion of the data base that allows an effective data retrieval for chemical exposure assessments, and it is now projected that this final data acquisition/tabulation effort will be completed and the data base made available to support such studies by spring of 1986. It should also be noted that the list of facility types included in NOHS was varied somewhat in the NOES survey. For example, agricultural facilities such as grain elevators and preparation services (i.e., facilities not generally sited in a scattered fashion in rural areas) were added to the survey. Conversely, certain financial institutions, most wholesale and retail trade establishments, and state and local government facilities were deleted from the study. Essentially the same guidelines used for the NOHS survey were employed in the design of the NOES†. (Contact Mr. David Sundin, NIOSH, 513-684-4491, for information on the status and availability of data from NOHS or NOES).

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*Personal communication between S. Mallinger, OSHA, and P. Desai, Versar Inc., February 1982.

†Personal communication between Dave Sundin, NIOSH, and L. Schultz, Versar Inc., November 1984.

NIOSH can also generate output in the form of maps which illustrate probable locations of occupational exposure for specific chemicals. The maps allow the access of data from a variety of perspectives, and at different levels of geographic resolution. The following list identifies the map types currently available:

- Distribution of potential exposure to selected chemical agents by Standard Industrial Classification (SIC) code.
- Frequency distribution analysis.
- Distribution of facilities within specified SICs.
- Distribution of facilities where workers are potentially exposed to selected chemical agents.
- Distribution of workers potentially exposed to selected chemical agents.
- Distribution of workers potentially exposed to a group of chemicals related to a specific health effect.
- Rank order listing of potential exposures by county.
- Listings of industrial facilities in which potential exposure is expected.

3.5.2 Occupational Safety and Health Administration

Monitoring for exposure in the workplace is performed for compliance with the OSHA standards and is conducted both by employers and by OSHA (Leidel et al. 1977). Although they have never required industry to supply monitoring data, OSHA does try to elicit such information voluntarily. One can request this information from companies directly, but companies are not obligated to provide it because it can be considered confidential.*

OSHA inspections of manufacturing facilities can include the following: (1) general scheduled inspection; (2) inspection in response to an accident; (3) inspection in response to a complaint; (4) a follow-up to a previous inspection, and (5) monitoring inspection. Information collected during an OSHA inspection includes the name and address of the establishment inspected; the date and type of inspection; the level of exposure and severity rating; the OSHA standard under which the inspection occurred; the number of employees at the facility and the number of persons exposed to the hazardous agent; and the SIC codes and corresponding job titles affected. The inspection records and test results are retained at the OSHA area office; these records represent a good source of independent measurements outside of industry.

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*Personal communication between S. Linhard, OSHA, and P. Desai, Versar Inc., December 1981.

The information collected by OSHA during their inspections is entered into a computerized system, the Management Information System (MIS). Information in MIS can be requested by anyone.* The health effects data contained in the MIS are organized into four reports (OHDS 1,2,3, and 4). Of these, OHDS 1,2, and 4 are useful in conducting occupational exposure assessments. OHDS 1 is an overall summary of health effects by chemical. It summarizes sampling conducted and presents results in comparison with the Permissible Exposure Level (PEL) for the chemical under evaluation. OHDS 2 provides the same type of information as does OHDS 1, but it is organized on a SIC code basis. OHDS 4 provides detailed reports of individual inspections. These contain the actual sampling results obtained for given site.†

Prior to 1979, there were several limitations in OSHA monitoring data. The inspection records were not in a standard format. Some inspection reports were very exact, describing the duration and levels of exposure for each process step. Other reports provided little information on the process involved or the resultant exposure. Actual levels of exposure were not recorded; instead, results were presented by severity codes, only in ranges, and only when the OSHA standard was exceeded. Also not recorded were the location of the exposure, the number of employees exposed, or whether safety measures, such as respirators, were used.

The monitoring data from state OSHA programs present some difficulties in availability and utility. Information from the states has to be requested from each state because the data are not automatically channeled to the federal OSHA offices. Industries were not uniformly monitored, and categories of violation (e.g., serious, nonserious, or repeat ratings) were not consistent. Information concerning such violations was not recorded, rendering understanding of an inconsistency impossible.Δ

When inspections were conducted in response to a complaint, the inspection was directed at the complaint area and not at the entire facility. Consequently, because about 80 percent of the inspections resulted from complaints (due to manpower limitations), the data were of limited use for estimating exposure under "normal" conditions.

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*Personal communication between C. Bascesta, OSHA, and P. Desai, Versar Inc., November 1981.

†Personal communication between Bill Wentling, OSHA, and L. Schultz Versar Inc., November 1984.

ΔPersonal communication between S. Mallinger, OSHA, and P. Desai, Versar Inc., February 1982.

For the above-mentioned reasons, the OSHA monitoring data gathered prior to 1979 were not conducive to industry-wide extrapolation. Significant changes made in 1979 by OSHA in the data base will facilitate the extrapolation of monitoring information to specific cases. Now recorded are: the measured TWA, job titles of people sampled, the SIC code, the exposure ceiling, whether a citation was issued, and if so, for what. These computerized results are now recorded in a standard format and provide more accurate detail from 1979 forward. A sample printout is provided in Appendix B.

In spite of this, it is still not always feasible to make extrapolations to the whole of industry from OSHA monitoring data. For example, data on the tannery industry are incomplete. Furthermore, although the specific process during which exposure occurs is recorded, this information is not entered in the computerized data base and thus is not readily available.*

Other information available from OSHA is contained in the OSHA Docket Files. This information consists of documents used as evidence for establishing OSHA standards. Documents include data from (1) industry - their comments on the proposed standards, data from health effects studies, and results of their occupational sampling and monitoring programs, and (2) trade unions or associations - their responses to proposed standards, records of occupational disease, and estimations of occupational exposure.

It is apparent from the preceding discussion that although OSHA may provide the best available occupational monitoring data, there are limitations inherent in their use. One problem is that the data base is far from complete; data are simply absent for many chemicals and potential exposure situations. The data that are available generally represent high exposures, and extrapolation throughout an industry or occupation can result in overestimation of occupational exposure. These problems, however, do not preclude the use of OSHA data. They simply point out the importance of using the data cautiously.

3.6 Summary

To assess occupational monitoring data for a given chemical, one needs to proceed as follows:

- Locate or identify exposure monitoring data, as measured in typical occupational settings.

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*Personal communication between C. Oliver, OSHA, and P. Desai, Versar, Inc., December 1981.

- Evaluate the obtained monitoring data in terms of their quality (QA/QC), representativeness (regarding worker categories or occupational situations), and appropriateness.

- Compare the data to any model projections that have been generated.

Occupational exposure monitoring data can be obtained by (a) searching the literature manually or on-line; (b) searching NIOSH publications, e.g., criteria documents, walk-through surveys, support documents for criteria standards; (c) searching OSHA records on monitoring via the Management Information System (MIS) on-line; (d) searching documents stored in the OSHA Docket Office, especially for records of monitoring as submitted by industry and trade unions; and (e) searching the National Occupational Health Survey (and the National Occupational Exposure Survey once it becomes accessible).

The evaluation of monitoring data quality and representativeness should address the extent to which a set of data represents the actual exposure of the worker. The following sections in this report should be consulted to aid in the evaluation of monitoring data:

Section 3.3 Sample Collection Techniques

Section 3.4 Exposure Measurement Strategies

Section 3.5, Available Information on Occupational Exposure, should be consulted for guidance in locating established standards and information on actual occupational exposure.

4.0 ESTIMATING CONTAMINANT RELEASES IN THE OCCUPATIONAL SETTING

4.1 Introduction

Occupational exposure to chemical substances associated with industrial manufacturing, processing, distribution, and use of products may result from chemical releases into workplace or ambient air and from direct contact with contaminated equipment, chemical substances, or processed material. The following are categories of chemical releases that may contribute to occupational exposure:

1. Releases from worker activities associated with industrial operations.
2. Releases from industrial stacks, process vents, fugitive sources, storage sources, and secondary sources in industrial processes.
3. Releases from products during activities associated with wholesale and retail trade.
4. Releases during commercial use of products.

This section discusses methods for estimating contaminant release rates in the occupational setting. Section 4.1.1 discusses the categories of chemical releases and their relations to potential occupational exposure. Section 4.1.2 describes the general mass balance approach to predicting contaminant releases in the absence of monitoring data. Section 4.1.3 presents algorithms that can be used within certain frameworks for estimating contaminant release rates from sources associated with industrial manufacturing, processing, distribution, and use of products.

4.1.1 Types of Contaminant Releases

Generic worker activities associated with industrial operations include drumming of liquids, drumming and bagging of solids, cleaning, maintenance, and sampling and analysis. These generic activities, either singly or in combination, are basic components of many broader industrial operations such as process troubleshooting; process development, which may include full-scale factory trials of new manufacturing procedures or technologies; and equipment installations. Chemical releases associated with broader industrial activities can be estimated by integrating predicted releases from all generic activities making up the overall operation.

Chemical releases associated with generic worker activities are generally short-term and periodic. Releases can lead directly to inhalation, ingestion, and dermal exposures for the workers performing

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the activity and indirectly to inhalation and ingestion exposures for others in the workplace.

Chemical releases from industrial stacks are dispersed in the ambient air and thus primarily contribute to contamination of the ambient environment rather than the workplace. Chemical releases from process vents occur during the operation of the process and, depending on the sizes and configurations of the vent and nearby buildings and structures, may contribute significantly to contamination of workplace air due to building wake effects (see Section 5 for discussion of this phenomenon). Chemical contaminants from industrial stacks and process vents generally are passed through an emission control device (e.g., electrostatic precipitators, flares, incinerators) prior to discharge to ambient air. These control devices may be quite effective in reducing volatile organic compound (VOC) releases to ambient, and possibly workplace, air. See Versar (1984b) for a detailed review of the efficiencies of combustion control devices for process sources in the synthetic organic chemical manufacturing industry (SOCMI). See Freed et al. (1983) for methods to assess exposure to chemical substances in the ambient environment.

Fugitive releases are principally emissions from leaks in the process equipment and from defective, inadequate, or worn seals in equipment such as pumps, valves, and compressors. They occur as a result of normal plant operations and are due to thermal and mechanical stresses. Releases from fugitive sources are initially releases to workplace air and, subsequently, ambient air (i.e., fugitive releases in an indoor workplace eventually are exhausted to the atmosphere through ventilation/exhaust ducts; fugitive releases in an outdoor workplace initially contaminate workplace air and, eventually, migrate into ambient air). Fugitive releases can be effectively controlled through leak detection and repair (LDAR) programs and use of several mechanical devices (e.g., seals, rupture disks). See Versar (1984b) for a summary of efficiencies of fugitive emission control systems in the SOCMI.

Storage releases are breathing losses that are vented from fixed-roof and floating-roof tanks used for storing volatile liquids. Storage tanks are usually located outdoors. The releases from storage may contribute to the overall plant area concentration.

Secondary releases are the emissions that result from the handling, treatment, and disposal of aqueous, liquid, and solid wastes generated by industry (ITE 1980). These may result in occupational exposure to workers around the treatment facility.

Releases from products during trade may occur as a result of package failure during loading, shelving, or sales, or during handling of unpackaged products. Workers engaging in wholesale and retail trade activities may experience inhalation exposure from the chemical releases and dermal exposure from direct contact with a product.

Commercial activities include most workplace situations other than manufacturing and trade; this sector is dominated by the service industries. The individual activities are too diverse for listing. As a group they generally involve passive inhalation exposure, which includes all exposures resulting from use of a product other than the active exposure of the user during use (e.g., exposures of the user and non-users following use activities).

4.1.2 The Mass Balance Approach

If accurate and reproducible workplace or personal breathing zone monitoring data, which quantify the contaminant levels in workplace air or the levels to which workers are exposed, are not available for industrial operations and related activities, then mass loadings of chemical substances to workplace air (and, subsequently, the air concentrations) must be estimated. Development of a mass balance involves prediction of a chemical's mass loadings to environmental media and workplace air from all emission sources in industrial manufacturing and processing operations and related activities so that emissions to the workplace can be quantified and distinguished from emissions to the ambient environment.

A mass balance for assessing chemical releases to workplace air from industrial manufacturing and processing and related activities consists of the steps outlined below. These steps comprise any mass balance approach for predicting chemical loadings to air regardless of the setting (i.e., workplace or ambient). However, an additional data integration component is requried when estimating chemical loadings to workplace air. The basic mass balance development steps involve:

- Identifying all sources of chemical (primarily volatile organic compound (VOC)) emissions to air in the process or activity. Chemical emissions may be vapors or contaminated particulates.

- Grouping emission sources into categories (e.g., stacks, vents, fugitives, storage) according to the nature of contaminant release (e.g., continuous or intermittent, process or activity related).

- Determining emission rates. For process sources, this step involves use of emission factors, which quantify mass loadings to air per unit of production volume, available in the literature for selected source categories in numerous industrial processes; production data for the process; and data on applicability and performance of emission control devices. For intermittent, short-term releases associated with worker activities, this step involves prediction of the release rate during the activity, using expressions based on chemical properties and characteristics of the operation.

- Determining constituent chemical release rates. For process sources, this step involves use of reported composition of emission streams from source categories in industrial processes (which are available in the literature); or estimation of emission stream compositions analyzing the process chemistry and unit operations. For releases associated with worker activities, the algorithms can be adjusted to predict releases of constituent chemicals that are components in a solution.

- Determining total mass loadings of constituent chemicals. This step involves integration of constituent chemical release rates with production data. Short-term, intermittent chemical release rates associated with worker activities must be integrated with data on the frequencies and durations of activities (which depend on production characteristics) to determine total loadings to air over time.

Chemical releases to workplace air during worker activities associated with industrial production are short-term, intermittent releases; just as for process sources, mass loadings of VOC or other chemicals for these worker activities depend on production volume and process characteristics. However, total mass loadings are more difficult to determine for worker activities than for process sources. Although release rates can be predicted for worker activities based on the physical and chemical properties of the chemical substance and the characteristics of the process activity, total mass loadings from these activities can be estimated only after the durations, frequencies, and other parameters associated with the worker activities and the production process are determined. For example, the frequencies, durations, and intensities of releases during maintenance activities at an industrial facility are highly dependent on, among other parameters, the degree of automation of process technology and the throughput of the system. In a modern petrochemical plant with high system throughput in continuous production operations, highly automated process control systems may be used to operate the process. Maintenance activities at this plant may involve breaking into a production line during process operation to repair an automatic control device. The duration and intensity of release associated with this activity may be much greater than a maintenance activity conducted at a small batch producer of specialty chemical products, where maintenance may involve replacing a worn valve during the downtime between process batches. Also, the frequency of maintenance activities at the two plants may vary greatly and may be difficult to predict. Thus, an additional data integration component is involved in the final step of a mass balance for predicting chemical loadings to workplace air from emission sources associated with worker activities.

4.1.3 Estimating Releases

Chemical releases to the occupational setting, whether indoors or outdoors, may be direct or indirect. Direct releases are those introductions of chemical contaminants into workplace air which directly result in exposure to the workers involved in the activities that cause the release. Indirect releases are those that affect workers not engaged in an activity that itself causes the release. Emissions from process vents as well as fugitive and storage emissions generally fall into this category. Note that from an exposure standpoint, a release may be considered both direct and indirect if it affects both classes of workers (i.e., those involved in the release-causing activity as well as those not involved).

Both direct and indirect releases of chemical substances in the workplace also may contribute to contamination of ambient air. If the releases are to an indoor workplace, they may be released to ambient air by building exhaust and ventilation systems; if releases are to outdoor workplaces, the contaminants immediately become a component of the ambient air.

Characterization of contaminant releases is of primary importance in assessing exposure to chemical substances in the occupational setting. Such releases increase the levels of contaminants in workplace air and may lead to exposure of the worker performing the activity or of other workers in the environs of the release. The following discussion centers on algorithms that can be used to predict rates of releases to the workplace. Input data required for estimating release rates using these algorithms include physical and chemical properties of the chemical substance and characteristics of the activity or operation. These data vary on a case-by-case basis; the algorithms should be used with site-specific data inputs. However, screening estimates of release rates can be derived from the algorithms using input data cited in Berman (1982), which presents ranges of values, typical values, and worst-case values of necessary input parameters.

(1) Worker activities. The following are five categories of worker activities associated with industrial manufacturing and processing that may contribute to occupational exposure to chemical substances:

- Drumming of liquids
- Handling of bulk solids (e.g., bagging, weighing)
- Cleaning of process components
- Maintenance of process components
- Sampling and analysis

Each type of worker activity may consist of several different operations that have unique release characteristics. Algorithms are presented for use in predicting release rates associated with a particular operation. Note that although this list includes the major categories of occupational exposure-related activities, it is not all inclusive. For example, workers sawing particle board containing urea-formaldehyde resins may experience significant exposure. Other such situations are expected to occur. Therefore, as this report can not address each discrete exposure situation in detail, the assessor should consider other potential routes of exposure in addition to those addressed here when conducting an exposure assessment in an occupational setting.

(a) Drumming of liquids. In drumming, liquids are dispensed through hoses draining a large reservoir of material (e.g., a reactor, a holding tank). Manufactures do not usually drum liquid products from industrial manufacturing operations; rather, the manufacturer ships the liquid products by rail car or road tank car to distributors and formulators who eventually drum the material for resale (Berman 1982).

Liquid may be fed into a drum either by splash loading or subsurface loading. During splash loading, turbulence may be substantial because the dispensing nozzle remains above the surface of the dispensed liquid. In subsurface loading, turbulence is minimized by extending the dispensing nozzle to the bottom of the drum to ensure that it remains submerged during the filling procedure. For most applications drums are splash loaded (Berman 1982).

During drumming of liquids, the major route of worker exposure is inhalation of contaminated air resulting from evaporation of bulk liquid. Generation rates of contaminant depend primarily on the vapor pressure and molecular mass of the liquid, the sizes of the drum and its access portal, the number of drums filled per unit time, and the temperature at which transfer is conducted.

An expression for estimating release rates of contaminants from volatilization of bulk liquid during drumming is reported in Berman (1982). The expression can be derived from the ideal gas law and can be tailored to predict release rates of chemical components of a bulk liquid. The expression can be used for calculating release rates if the following are assumed:

1. The system is at constant temperature and pressure.

2. The volume of vapor generated from volatilization of bulk liquid (or components of the liquid) is proportional to the volume of liquid drummed.

3. The gases behave ideally. The ideal gas law applies, and the partial pressure of a gas above the liquid is proportional to the vapor pressure of the substance.

4. Henry's law applies for estimating partial pressures of components of a bulk liquid.

The expression is as follows:

$$G = \frac{(MW)\ (P^{\circ})\ (f)\ (V_{drum})\ (r)}{(3600)\ (R)\ (T)} \qquad (4\text{-}1)$$

where

G = constant rate of contaminant release from evaporation of bulk liquid during drumming, grams per second
MW = molecular weight of chemical substance, grams per gram-mole
P° = vapor pressure of the pure contaminant at temperature T, atmospheres
f = saturation factor; 1 for splash loading and 0.5 for subsurface loading (Berman 1982)*
V_{drum} = volume of a drum, cubic centimeters
r = filling rate in drums per unit time
R = universal gas constant; 82.05 (cubic centimeters) (atmosphere)/(gram-moles) (degrees Kelvin)
T = temperature, degrees Kelvin

If the contaminant of interest is only a component of a solution being transferred; the release rate expression must be modified slightly. For components, the vapor pressure of the pure substance, P°, is replaced by P', which is the partial pressure of the component derived as follows:

$$P' = (H)(X) \qquad (4\text{-}2)$$

where

H = a Henry's law constant
X = mole fraction of the component

Substituting expression (4-2) into (4-1), the following expression for release rate is obtained:

$$G = \frac{(MW)\ (H)\ (X)\ (f)\ (V_{drum})\ (r)}{(3600)\ (R)\ (T)} \qquad (4\text{-}3)$$

Whether operations use a passive drainage system that relies on gravity feed or on active pumping system, drumming of liquids generally involves little splashing and spilling of material because of the small size of a drum's orifice relative to the access portal on a large process or storage tank. Thus, dermal contact with the liquid is not a probable route of exposure if standard operating procedures are followed (Berman 1982).

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*Note that these values should be considered "worst-case" saturation factors for use when activity- and chemical-specific data are unavailable. In practice, the analyst should investigate the availability of such specific data for use in this equation before applying these default values.

(b) Drumming and bagging of solids. Drumming and bagging of bulk solids pose a great potential for inhalation and dermal worker exposure. The major source of contamination from bulk solids handling operations is the generation of dust from the agitation of particulate material during transfer operations. Exposure can result from inhalation of respirable airborne dust. Dermal exposure can result from airborne dust that settles on and adheres to the skin and clothing of workers.

The level of dust released during drumming and bagging of bulk solids depends on characteristics of the operations and properties of the solid.

Bagging and drumming operations for bulk solids may be manual, automated, or any combination of the two. Fully automated systems tend to be enclosed, well-ventilated operations where attendant exposure is minimal. Berman (1982) stated that such systems are economical only if the volume of material handled exceeds 100,000 pounds per year. For smaller solids handling operations, many solids are bagged using semi-automated procedures. A semi-automated operation may consist of a hopper that automatically dispenses a predetermined quantity of material into a bag. The bag is then moved to a sealing station (e.g., a stapling machine). After sealing, the bag is loaded for shipment.

Properties of the solid that are pertinent to the extent of dust formation include particle size, density, shape, and surface characteristics and bulk properties such as size distribution, moisture content, and extent of aeration.

An empirical relation correlating these parameters with the rate of dust generation has not as yet been developed. As the experimental data base expands, empirical methods for estimating dust generation rates will be developed.

Limited monitoring data reporting concentrations of suspended particulates associated with bagging and related solids handling operations are cited in Berman (1982). These data may be used as source strengths in calculating inhalation exposures; however, the fraction of airborne particulates that is respirable must be estimated or assumed. Alternatively, it is useful to note that dust standards developed by the Occupational Safety and Health Administration may be used to estimate likely air concentrations in the absence of actual dust generation data.

(c) Cleaning. Short-term, but potentially significant, contaminant releases may result from cleaning process equipment. Cleaning operations usually require breaking of a production line or dismantling of equipment.

Cleaning involves the removal of residual material from storage tanks, holding tanks, stills, reaction vessels, pipework, and other process equipment. The broad ranges of size, shape, accessibility, and mobility of process equipment require a variety of cleaning procedures. Effective cleaning procedures must address properties of the material to be removed. Current general cleaning practices include washing, solvent rinsing, steam cleaning, and scraping and shoveling; these may be performed individually or in combination.

Process equipment must be purged of mobile material prior to cleaning. Purging and opening of process equipment prior to cleaning can be high exposure activities for industrial workers.

(i) Purging. Contaminant releases associated with purging are primarily a function of the physical state of the material to be purged. Purging of gaseous materials requires sealed equipment so that, except for fugitive emissions, releases likely are minimal. Liquid sludges or residues are frequently drained by a trap into waste drums. Contaminant release rates associated with this activity parallel those associated with drumming of liquids (see expressions (4-1) and (4-3) for the generation rate); however, the vapor released during purging may be saturated because equipment is frequently heated to facilitate purging of otherwise viscous residues. Solid residues that are sufficiently mobile are purged from process equipment in a manner that can be approximated by the conditions associated with bagging and drumming of solids (Berman 1982).

(ii) Opening. Access required for cleaning is provided by breaking of a line or opening of process equipment. If the compartment to be opened is at ambient pressure, then the principal cause of workplace contamination is diffusion of volatilized material from within the compartment. If a positive pressure exists in the process equipment to be opened, then the pressure gradient that exists when the line is opened will accelerate transport of the contaminant into workplace air.

The rate of contaminant release associated with the opening of process equipment varies with time. The initial release rate will be maximum; the release rate will diminish with time (Berman 1982). This is because, unlike the saturated surface adjacent to a liquid, the surface by the opening will not remain saturated. The rate at which saturation at this surface is renewed is limited by the rate that the contaminant inside the enclosure will diffuse from residual material to the vicinity of the opening. Thus, the initial contaminant release rate from an aperture represents an upper limit to the actual release rate.

The initial contaminant release rate from an aperture is primarily a function of the properties of the residual material and the size of the opening or aperture. Just as evaporation is limited by diffusion away from a saturated interface adjacent to the surface of a liquid, the initial comtaminant release rate from an aperture is limited by the diffusion rate away from a saturated aperture surface. Thus, the initial contaminant release rate from an aperture is obtained from the following relationship (Berman 1982):

$$G = \frac{(MW)\,(K)\,(A)\,(P^{\circ})}{(R)\,(T)} \qquad (4\text{-}4)$$

where

G = initial contaminant release rate of contaminant, grams per second
MW = molecular weight of the contaminant, grams per gram-mole
K = gas phase mass transfer coefficient of the contaminant, centimeters per second
A = area of the aperture, square centimeters
P° = vapor pressure of the contaminant, atmospheres
R = universal gas constant, (cubic centimeters) (atmospheres)/(gram-mole) (degrees Kelvin)
T = absolute temperature, degrees Kelvin

The contaminant release rate obtained from expression (4-4) corresponds to evaporation of bulk liquid or solids. If the contaminant of interest is only a component of a liquid or solids solution in the residue, the release rate expression must be modified slightly. For components, the vapor pressure of the pure substance, P°, is replaced by P', which is the partial pressure of the component derived as previously indicated in expression (4-2).

Substituting expression (4-2) into (4-4), the expression for contaminant generation rate becomes the following:

$$G = \frac{(MW)\,(K)\,(A)\,(H)(X)}{(R)\,(T)} \qquad (4\text{-}5)$$

(iii) Water washing. Process equipment may be washed with water to remove water-soluble materials and non-adhering particulates. Detergents are frequently added to increase removal efficiency. The contaminant release rate due to volatilization of residual material decreases as water is added to an opened compartment because the residue enters solution or suspension (Berman 1982). Thus, significant release of contaminant associated with washing is only expected to occur during purging and opening in preparation for washing. (See previous sections 4.1.3(1)c(i and ii)). Also, a worker may experience direct dermal contact with contaminanted equipment, solid residues, or contaminated solutions during water washing of process equipment.

(iv) Solvent rinsing. Materials not readily removed by water washing may be cleaned using solvents other than water. In some cases, the equipment is heated to increase the solubility of residue. Assuming that the solvent does not boil, which is reasonable since solvent vapor would present a much greater hazard than vapor from residual material, the maximum contaminant release rate (which corresponds to the initial release rate) is limited by the rate at which vapors diffuse into the workplace from a saturated aperture surface. Thus, the contaminant release rate expressions (4-4) and (4-5) for opening of process equipment are also applicable to solvent rinsing (Berman 1982).

(v) Steam cleaning. Nonvolatile solids that resist cleaning by washing or rinsing are frequently removed using steam. During steam cleaning, steam is delivered by hose to an isolated section of process equipment. Steam condenses on the walls of the vessel and the resulting water, laden with residual material, is drained via a tap at the bottom of the vessel. Contaminant releases associated with steam cleaning of process equipment are likely to be small if steam cleaning follows other cleaning measures (during which initial significant releases of contaminant occur) and the volatile components in the residue not removed by the steam cleaning are minimal. If these conditions do not apply to the steam cleaning operation, then expressions (4-4) and (4-5) (which were developed for predicting contaminant release rates during opening of process equipment) may be used to determine a reasonable upper limit to contaminant release rates during steam cleaning (since these releases likely will not be greater than the initial contaminant releases that occur when process components are opened).

(vi) Shoveling and scraping. Solid materials that cannot be removed by other cleaning methods must ultimately be removed by manual shoveling and scraping. Depending on the size of process equipment, a worker can manually clean equipment either externally or internally. Usually, small process components are cleaned externally and large process components are cleaned internally.

Contamination of workplace air from vapor generated inside a vessel is limited by diffusion through the access aperture. Thus, a maximum contaminant release rate during external manual cleaning of small process components can be estimated using expressions (4-4) and (4-5), which are release rate expressions for opening of process equipment. However, unlike during the initial opening of a sealed compartment, a worker may experience direct dermal contact with contaminated equipment or residual material during external manual cleaning.

Workers may physically enter large process components such as storage and holding tanks and reactor vessels. Generally, an industrial worker enters a process vessel to manually remove solid residual material still remaining after completion of other cleaning methods (e.g., purging, water washing, solvent rinsing, steam cleaning). Much contaminant release may occur during the precleaning steps, before the worker enters the vessel; however, air in the vessel may be saturated with vapor or dust from residual material, particularly since ventilation in such enclosures is poor (Berman 1982).

If the facility strictly adheres to a worker safety program, the worker entering the vessel should be wearing a respirator (and other protective equipment, such as special clothing and gloves to minimize dermal contact). In this case, worker inhalation exposure would be reduced or eliminated depending on the efficacy of the protective measures used (see Section 7.2). If the facility does not strictly adhere to a worker safety program, then the worker may enter the vessel without wearing a protective device. Assuming in the worst case that the vessel air is saturated with contaminant, then the maximum air concentration of contaminant can be computed from the ideal gas law with the saturation vapor pressure of the chemical substance as the input pressure; the rate of contaminant release does not need to be estimated.

The ideal gas law is:

$$PV = nRT \tag{4-6}$$

where

P = pressure of gas
V = volume of gas
n = moles of gas
R = universal gas constant
T = temperature of gas

The number of moles of gas, n, is equivalent to m/MW, where m is the mass of gas and MW is the molecular weight of the gas. Inputting P°, the saturation vapor pressure of the liquid contaminant at temperature T, for P and m/MW for n in expression (4-6), the following is obtained:

$$\frac{m}{V} = C = \frac{(P^\circ)\,(MW)}{(R)\,(T)} \tag{4-7}$$

where

m = mass of gas, grams
V = volume of gas, cubic centimeters
C = worst-case (saturation) concentration of contaminant in the interior of process component, grams per cubic-centimeter
P° = saturation vapor pressure of liquid contaminant at temperature T, atmospheres
MW = molecular weight of the contaminant, grams per gram-mole
R = universal gas constant = 82.05 (cm^3-atm)/(gram-mole) (°K)
T = absolute temperature, degrees Kelvin

Dermal contact during internal manual cleaning of a process component may be excessive in the absence of protective clothing and other special measures.

(d) Maintenance. Maintenance involves the mechanical adjustment, alteration, or repair of engineering equipment. The following are examples of maintenance activities: replacing valve seals, repacking stirrer glands, repairing pipework and flanges, servicing motors and pumps, and calibrating monitoring instruments. Maintenance operations can be classified into the following groups:

- Those performed externally to process equipment.
- Those performed via access portals and other openings in process equipment.
- Those requiring workers to enter process enclosures.

Operations in each group possess similar characteristics that are pertinent to contaminant releases. These operations are individually discussed below.

(i) Operations performed externally to process equipment. Maintenance operations that can be performed externally to process equipment and do not require the breaking of any seals present little potential for contaminant release to air. The only releases of contaminant are fugitive emissions, which can be considered relatively insignificant. There is a potential for workers to dermally contact chemical residues remaining on equipment due to poor cleaning practices. Examples of maintenance operations in this category include adjusting instruments, tightening bolts or seals, repairing pump motors, and monitoring.

(ii) Operations performed via access portals and other openings. The majority of maintenance operations are performed via access portals and other openings (e.g., replacing valves or flange seals, repacking stirrer glands, repairing or replacing pipework, changing filters). Access required for these operations is provided by breaking a line or opening process equipment. Thus, contaminant releases associated with such operations are due to diffusion of residual vapors through the access aperture into the workplace.

Expressions (4-4) and (4-5) for contaminant release rates, developed for releases during opening of process components, are also appropriate for estimating release rates for maintenance activities performed via access portals and other openings. They are applicable for release rate estimations during changing of filters. However, rather than an open aperture, filters represent a surface coated with material that volatilizes causing airborne contamination. As the material volatilizes, the space adjacent to the surface becomes saturated with vapor. The contaminant release rate to workplace air from filter changing is therefore determined by the rate vapors will diffuse from such a saturated layer (Berman 1982). To determine the contaminant release rate associated with changing a filter, expressions (4-4) and (4-5) can be used with the surface area of the filter (rather than an aperture size) being substituted for the parameter "A."

Dermal contact may be significant for workers conducting maintenance activities via access portals and other openings.

(iii) Operations requiring workers to enter process enclosures. Repair of internal components or the interior walls of large process equipment such as tanks and reaction vessels frequently requires maintenance workers to enter such compartments. Although workers in such situations would generally be expected to use protective equipment such as a respirator (see Section 7.1), that may not always occur. The contaminant release rates associated with these maintenance activities are not predicted in this report; rather, it is assumed that the worst-case contaminant concentration (to which the worker may be exposed when not wearing a respirator) inside the equipment is represented by the saturation concentration of the contaminant, just as for internal manual cleaning of process components discussed previously in Section 4.1.3(c)(vi). The saturation concentration of the contaminant in air can be determined using the ideal gas law with the contaminant's saturation vapor pressure as the input pressure. See expression (4-7) for guidance on estimating saturation concentrations. The saturation concentration can easily be attained during maintenance operations conducted inside process equipment because of poor ventilation in the enclosure and a large contaminated surface area in the vessel's interior (Berman 1982).

Dermal contact may be significant for a maintenance worker inside a process vessel.

(e) Sampling and Analysis. Sampling and analysis operations include a diverse set of procedures that present a broad range of potential for worker exposure. Even in small industrial manufacturing operations, most sampling and analysis operations are performed by automatic devices incorporated directly into process lines and equipment. On-line sampling and analysis offer advantages such as continuous monitoring capability, rapid results, and decreased labor costs. Worker exposure associated with automated sampling and analysis results primarily from fugitive emissions (Berman 1982).

Manual sampling and analysis, which may be common in small batch operations and in processes requiring measurement of physical parameters (e.g., specific gravity, viscosity, clarity, or suspended solids content) pose potentially significant contaminant releases. Contaminant releases associated with manual sampling and analysis depend on the specific procedures used and the physical state (e.g., solid, liquid, gas) of the material being sampled. For example, sampling of gases requires use of equipment that is attached directly to the production line to confine the gas; except for fugitive emissions and a small volume of vapor released when a sampling device is uncoupled, contaminant releases associated with gas sampling should be minimal.

Sampling of liquids and solids may result in contaminant releases to workplace air from volatilization of the material or diffusion of saturated vapor. The former mechanism of contaminant release may predominate if the sampled material lies in an uncovered vessel during sampling (e.g., sampling by dipping a scoop or glass tube into the liquid to obtain a small quantity of liquid). The latter mechanism of contaminant release may predominate if the vessel is sealed and a small access portal is opened for sampling.

Many factors (e.g., the duration of the sampling operation, the size of the sampling access aperture, the volume of the sample, the molecular weight of the chemical substance) determine the relative contributions of direct volatilization and diffusion of saturated vapor to contaminant releases during sampling operations. These factors vary on a case-by-base basis.

The contaminant release rate associated with displacement of saturated vapor during sampling is derived from the ideal gas law and parallels that of drumming of liquids (see expressions (4-1) and (4-3) in this section). The expression is as follows (Berman 1982):

$$G = \frac{(V)\ (P^{\circ})\ (MW)}{(r)\ (R)\ (T)} \qquad (4\text{-}8)$$

where

G = contaminant generation rate for displacement of saturated vapor, grams per second
V = volume of the sampling container or dipper, cubic centimeters
P° = vapor pressure of the liquid, atmospheres
MW = molecular weight of the liquid, grams per gram-mole
r = filling time of sampling device, seconds per container
R = universal gas constant, 82.05 cm^3-atm/gmole-°K
T = absolute temperature, °K

The contaminant release rate expression for volatilization of residual material during sampling parallels the expressions developed for estimating releases from volatilization during opening of process equipment. The initial release rate, which is the maximum release rate that can be used as an upper limit, from the sampling access portal may be limited by the diffusion rate away from the saturated portal "surface." Thus, the initial contaminant release rate for volatilization during sampling operations can be estimated using expressions (4-4) and (4-5) in this section.

Berman (1982) used typical and worst-case values of parameters in the contaminant release rate expressions for sampling operations to assess the relative contributions to releases from volatilization and displacement. Using parameter values typical of sampling operations in expression (4-8), the following expression for release rate due to displacement is obtained:

$$G = (6 \times 10^{-4})\ P^{\circ} \tag{4-9}$$

where G and P° are as defined earlier. Using typical parameter values in expression (4-4), the following expression for release rate due to volatilization is obtained:

$$G = (0.14)\ P^{\circ} \tag{4-10}$$

where G and P° are as defined earlier. Since (0.14)P° is so much greater than (0.0006)P°, it can be concluded that volatilization predominates (and displacement can be ignored) in typical sampling operations.

Using the reasonable worst-case values for parameters in expressions (4-4) and (4-8), Berman (1982) obtained the following reduced expressions:

$$G = (7 \times 10^{-2})\ P^{\circ} \tag{4-11}$$

for the release rate due to displacement and

$$G = (2.1)\ P^{\circ} \tag{4-12}$$

for the release rate due to volatilization. Thus, since (2.1)P° is significantly greater than (0.07)P°, it can be concluded that volatilization predominates in these situations as well. Both expressions (4-4) for volatilization and (4-8) for displacement should be used when contaminant release rates during sampling operations are estimated. Though it has been shown that volatilization may be the predominant mechanism of contaminant release during sampling, the relative contributions of the two mechanisms to the overall release rate should be assessed on a case-by-case basis using site-specific data.

A simpler method for obtaining samples is via a tap. In this case, sampled material is drained directly from sealed lines or a sealed vessel into a sample container. The resulting contaminant release is due to volatilization as the material fills the sampling tube. The contaminant release rate associated with tapping can be obtained using the volatilization expressions (4-4) and (4-6) in this section.

(2) Process sources. The following steps can be taken to quantify chemical mass loadings to air from process emission sources (which include stack vents, fugitive sources, storage sources, and secondary sources) in industrial manufacturing and processing operations:

1. Identify all VOC emission source in the process from process diagrams.

2. Group each VOC emission source into appropriate source categories.

3. Obtain uncontrolled VOC emission factors for each process source category. Versar (1983) has an abundance of useful information on industrial sources including emission factors, methods for mass balance calculations, control technologies, process descriptions and technologies, and economic factors. Appendices that accompany Versar (1983) provide a resource list identifying other valuable data sources, general process and industry-wide information, and data bases useful in estimating emissions.

4. Determine controlled VOC emission factors for each process source category. These factors are computed by multiplying the uncontrolled VOC factors by the quantity one minus the efficiency of the control device. Thus, control technologies must be reviewed for applicability and performance. Useful sources in this step include Versar (1983), SAI (1982), McDaniel (1983), USEPA (1980c), USEPA (1980d), and USEPA (1984), and Versar (1984a).

5. Determine compositions of each VOC emission stream in the process source categories. A useful source in this step is USEPA (1980e), which cites compositions of VOC emission streams in selected source categories and industrial processes as determined from monitoring. If composition data are not available in the literature for particular streams of interest, then the process chemistry and unit operations should be analyzed to estimate compositions.

6. Estimate controlled constituent chemical emission factors for each source in the source categories. These values are computed by taking the product of the controlled VOC emission factors and the constituent chemical composition in the stream.

7. Aggregate the controlled constituent chemical emission factors within each source category to obtain total chemical release factors for each source category.

8. For each source category, multiply the controlled constituent chemical emission factors by the production volume associated with the process to obtain total controlled chemical release rates.

Production volumes can be obtained from industry contacts, SRI (1984), and USITC (1984). Overall chemical releases for the process can be determined by summing the release rates over all source categories.

Process release sources continuously emit chemical substances to ambient air. These releases may or may not significantly contribute to contaminant concentrations in workplace air. Releases from vents could contribute to workplace air concentrations through wake effects created by structures in the vicinity of release. Section 5 discusses means of estimating concentrations of contaminants resulting from releases captured by building wakes. Fugitive releases initially are to workplace air and eventually diffuse or are carried to the atmosphere. Storage releases essentially contaminate ambient air since storage tanks are generally located outdoors in relatively isolated areas which are readily accessible by rail or motor carrier. Secondary releases may directly contribute to workplace air contamination in the vicinity of the treatment facilities and operations. The contribution of process releases to workplace air concentrations can only be accurately assessed by monitoring the contaminant levels in the air.

(3) Activities of wholesale and retail trade. The activities of workers in wholesale and retail trade can be grouped in six classes: loading, storage, packaging, shelving, demonstration, and sales. The extent to which any of these activities are pertinent to potential releases of contaminant to workplace air depends on the applications and uses of the finished products..

(i) Loading. Finished products are shipped from the manufacturing site to distributors, often wholesale traders. Loading (as a trade activity) is defined as the removal of a product from a transportation vehicle and the product's placement in a storage facility for subsequent sale. This definition includes the transition between manufacturing and trade as well as between wholesale trade and retail trade. It is a short-term activity with potential for direct releases of contaminant to workplace air and for dermal contact.

Loading may involve the handling of either bulk or packaged material. The degree of containment of a product will largely determine whether loading is a source of contaminant release. Accidents during loading may be another source of contaminant release to the workplace.

(ii) Storage. Loading of a product is usually followed by some period of storage. The storage area may be a separate warehouse facility or a section of a retail store. As in the case of loading, the degree to which storage may be a release source depends on the degree of containment or packaging of a product. Unlike loading, storage may be a long-term activity. Release of chemicals into the area may lead to accumulation of atmospheric contaminants over the long term, and storage facilities may not be designed with adequate ventilation for pollutant removal. Storage may also refer to the time a product resides in retail inventory (or on the shelf).

(iii) Packaging. Packaging may be done at the manufacturing site; this can involve the packaging of bulk materials for ease of transpor- tation or the packaging that accompanies a product through retail trade. Wholesale traders may take bulk shipments of goods and package them in "trade name" wrappings. It is through this activity that contaminant release may occur in the trade sector.

(iv) Shelving. Shelving involves the transfer of goods from storage to an area accessible to potential buyers. Shelving may be a source of contaminant release through accidental loss of product due to container failure (e.g., breakage of glass jars).

(v) Demonstration. Sale of an item may involve a demonstration of its use. For such a demonstration to be effective, it should closely mimic the consumer's use of the product. See Versar (1985b) for methods of estimating releases during consumer use of products.

(vi) Sales. "Sales" refers to the transfer of goods from the trade sector to the consumer or commercial user. The activities that are a part of selling vary widely with the product, but in all cases the sale is consummated in a short period of time. Sales may be a source of contaminant release through accidental loss of product (as in shelving).

The activities of wholesale and retail trade may be sources of contaminant release to workplace air in two possible ways:

- Accidental loss of product through package failure (loading, shelving, sales).
- Lack of packaging or insufficient containerization of product with resultant atmospheric emissions (loading, storage).

Also, direct contact with a product during packaging, contact resulting from package failure (leakage) during loading or demonstration, and other related activities can result in dermal occupational exposure.

Estimation of contaminant release rates from package failure requires three data inputs:

1. Product formulation
2. Volume of product in each discrete package
3. Package failure rate

Product formulation data can be obtained from Gosselin (1976), the NIOSH NOHS/NOES survey data bases (see Section 3), Bennett 1933-1981, economic data bases, and patent literature.

The volume of a product contained in each package can be determined in two ways. The first, direct observation, is preferred for consumer products; the investigator can simply go to a sales outlet and check product labels. Esoteric products not easily found on retail shelves can be quantified by contacting the producer or specialized merchants. The type of package can be determined in the same manner.

Failure rates of packages are not readily available. The wide variety of packages used (e.g., glass jars and bottles, plastic bags, tubes) have different failure rates. However, packaged materials are finished goods, and the economics dictate minimization of the failure rate.

Contaminant release rates as a result of package failure can be estimated using the following expression:

$$G = Fr \times V \times Fc \times N \quad (4\text{-}13)$$

or

$$G = Fr \times m \times Fc \times N \quad (4\text{-}14)$$

where

G = contaminant release rate due to package failure, grams or cubic centimeters per unit time

Fr = fraction of chemical in product formulation, fraction of total product mass or volume

V = volume of product in each container, cubic centimeters product per container

Fc = failure rate of containers, number of failed containers per unit time

N = total number of containers

m = mass of product in each container, grams product per container.

Expression (4-13) gives an aggregate mass loading or volume of contaminant into workplace air from package failures over a period of time. Site-specific data on standard operating protocols and capacities for conducting these activities are needed to assess contaminant releases from certain finished products on a case-by-case basis. Monitoring the air levels in workplaces during wholesale and retail trade activities is the preferred method for obtaining contaminant source strengths for calculating occupational exposures.

(4) Activities and processes of commercial use. The activities of commercial use include most workplace situations outside manufacturing and trade; this sector is dominated by the service industries. Table 4-1 lists the industrial classifications included in this category.

The actual activities within each commercial use industry are so diverse that they cannot be listed. Use data for a chemical and its products must be obtained from producers, distributors, and wholesale or retail dealers of the product to generate a comprehensive list of commercial users.

The methods for estimating releases from the active use of commercial products presented in Versar (1985b) are applicable to most commercial use situations. However, these and other methods for estimating contaminant releases should address the physical and chemical properties of the product; the purpose of, and activities related to, product use; and product use patterns. Methods need to accommodate these and other relevant data and should be validated to ensure proper use and accurate results. In the absence of complete and valid prediction methods, monitoring data gathered during active use of commercial products provide the only viable means of obtaining contaminant concentrations in air for use in calculating occupational inhalation exposures.

Table 4-1. Commercial Use Industries*

Agricultural services
Building construction - general contractors and operative builders
Construction other than building construction - general contractors
Construction - special trade contractors
Hotels, rooming houses, camps, and other lodging places
Personal services
Business services
Automotive repair, services, and garages
Miscellaneous repair services
Motion pictures
Amusement and recreation services, except motion pictures
Health services
Educational services
Miscellaneous services
Justice, public order, and safety

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*These designations refer primarily to the consumer industry.

Source: OMB 1972.

5. ENVIRONMENTAL FATE AND EXPOSURE PATHWAYS

The single route of exposure significantly affected by environmental fate processes in the occupational setting is that of exposure to airborne contaminants. While direct exposure to raw materials, process streams, or waste streams may be significant, the contaminant concentrations to which workers are exposed in these situations are determined by process parameters and are usually not modified by environmental fate mechanisms.

Section 4 provides methods for estimating the rate of contaminant release to the air from sources typical to the workplace. These release rates can be used in conjunction with algorithms describing significant air fate processes to obtain estimates of workplace air contaminant concentrations. Section 5.1 discusses fate processes affecting contaminants in the occupational setting. Means of calculating (estimating) workplace concentrations of such contaminants are presented in Sections 5.2 and 5.3. Procedures are presented for contaminant concentration estimation in two workplace settings: indoor and outdoor. In this context, outdoor workplace settings are considered to be those wherein a worker is exposed to contaminants caught by a building's wind wake. An example would be loading dock workers when the loading dock is located below a rooftop vent releasing contaminants to the outside air. For situations where workers are located outside and away from buildings or other structures that can cause a building wake effect but within reasonable proximity to contaminant release sources, the only reliable method of determining the concentration of chemicals to which exposure occurs is by monitoring. Note that this section does not address estimation of contaminant concentrations offsite in the ambient environment. Such procedures are presented in detail in Volume 2 of this report series (Freed et al. 1985).

5.1 Workplace Air Contaminant Fate Processes

For the purposes of this presentation, air fate processes are categorized into two groups below: those physical transport mechanisms that affect the movement of airborne contaminants from the source to the receptor and those physical and chemical mechanisms that remove airborne contaminants from workplace air.

5.1.1 Indoor Transport Processes

Two physical transport mechanisms, convection and diffusion, account for the movement of airborne pollutants in an indoor air space. The former mechanism predominates in rooms with significant air movement, while the latter is significant only in static indoor air environments.

Although both of these mechanisms can significantly affect the concentration of airborne pollutants at different locations within a room, theoretical relationships describing these effects and estimating air pollutant concentration differentials at selected spatial and temporal intervals are not available. Concentrations and exposure are usually estimated through use of room-wide average air concentrations as a function of time. The following discussions of the effects of diffusion and convection are provided for the purpose of permitting a qualitative assessment of concentration profiles within a room.

(1) Diffusion. Diffusion describes the movement of gaseous pollutants from areas of high concentration to areas of low concentration; it progresses at a rate dependent on room air temperature and pressure and on pollutant-specific physical and chemical properties (Treybal 1968). When conservative pollutants (i.e., those that do not readily degrade) are released from a finite source, the ultimate result of diffusion is a homogeneous pollutant concentration throughout the air of a room, where final pollutant concentration is a function of (1) the mass of pollutant released into the room and (2) room volume. When the source of the pollutant is in excess, final room air concentration is a function of (1) partitioning of the pollutant among gaseous and other media or (2) the air saturation concentration of the pollutant.

Prior to the establishment of homogeneous conditions, when pollutant releases are constant, or when dealing with nonconservative pollutants, air pollutant concentrations resulting from diffusion usually decrease with distance from the source.

(2) Convection. Convective currents transport both gaseous and particulate pollutants. Convection within a room results in air mixing, while convective transport associated with air movement into or out of a room results in room ventilation. The effect of these processes on room air concentrations are interrelated, as discussed below.

The effect of mixing, or convective transport within an indoor space due to air circulation or turbulence is to distribute airborne pollutants to those areas within the room which are affected by convective currents. The degree of distribution and concentration of pollutants at selected points is dependent on (1) directional patterns and velocities of air currents with relation to source locations, (2) aerodynamics of the room, and (3) the room's internal obstructions to air flow.

In ventilated rooms, mixing affects the efficiency of ventilation systems in removing airborne pollutants. Maximum ventilation efficiency occurs under theoretically perfect mixing conditions, in which mixing is complete and instantaneous and air pollutant concentrations are always homogeneous throughout the room. Because in practice mixing processes are not instantaneous and affect some areas of a room less than others, the efficiency of ventilation processes in a given room is reduced by a room-specific mixing factor. This mixing factor is usually determined empirically through tracer gas studies and is a function of room size, activity, and ventilation system configuration (Clement 1981). Typical mixing factors for a 1,000 cubic foot room are presented in Table 5-1. The use of mixing factors in estimating room air pollutant concentrations is described in the following subsection.

5.1.2 Indoor Air Contaminant Removal Mechanisms

Mechanisms that effectively remove airborne contaminants from indoor air fall into three categories: convective transport (i.e., ventilation), gravitational settling, and chemical degradation. Of the three, ventilation is usually the predominating mechanism; ventilation removal rates usually limit the room air residence time of airborne pollutants to under 2.5 hours (Versar 1984b), an interval often too brief for significant chemical decay or settling processes to take place. Ventilation is also the only process of these three which is usually accounted for in the calculation of room air pollutant concentrations. The following discussion briefly describes the manner in which each of these removal processes affects room air contaminant concentrations. Basic expressions illustrating the interrelationship of these processes and contaminant concentrations are also presented.*

(1) Ventilation. The effect of ventilation on room air contaminant concentrations is a function of ventilation rates, room volume, and mixing within the room. Ventilation is usually expressed in units of exchanges per hour, where one exchange represents the

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*Note that the following expressions for estimating workplace air contaminant concentrations address equilibrium concentrations within the entire room. In reality, however, workers often are exposed to localized concentrations in the immediate vicinity of the release source (i.e., the "effected volume"). Such local concentrations will significantly exceed those estimated for large workplace air volumes in equilibrium. Similarly, for exposure-related activities of short duration (e.g., less than 2 to 3 hours), development of time-weighted concentration values will more accurately reflect the actual exposure situation. When data allow, therefore, calculation of time-weighted, effected volume concentrations may provide the most accurate exposure estimates.

Table 5-1. Mixing Factor (m) Values for 1000 ft^3 Room

Air supply system	Mixing factor
Perforated ceiling	0.5
Trunk system with anemostats (central system controlled by pressure differentials)	0.33
Trunk system with diffusers (central system with forced-air blowers)	0.25
Natural draft with ceiling exhaust fans	0.16
Infiltration and natural draft	0.10

Source: Clement 1981.

infiltration of a volume of external air equal to the volume of the room. Typical exchange rates range from 0.5 per hour to 4 per hour (Versar 1984b), and suggested exchange rates for occupational settings range as high as 20 per hour (Versar 1984b, from ANSI/ASHRAE recommended commercial ventilation rates).

In cases where indoor contaminant releases are instantaneous and external air is free of pollutants, ventilation reduces the concentration of pollutants in room air over time following a pollutant release. Room air pollutant concentration as a function of time can be estimated by the following equation (Versar 1984b, from Porter 1983):

$$C = (P/V)\, e^{-m(Q/V)t} \tag{5-1}$$

where C = room air pollutant concentration at time t (g/m^3)
P = mass of pollutant initially released to room air (grams)
V = room volume (m^3)
m = mixing factor
Q = ventilation air infiltration rate (m^3/hr)
t = time from pollutant release event (hours)

In the case of a constant, steady-state pollutant release from an internal source and pure air ventilation from outside of the room, the room air concentration is a function of the ratio of the release rate to the ventilation rate, and of time. This function is represented by the following equation (Versar 1984b, from Porter 1983):

$$C = G/Q - (G/Q)\, e^{-m(Q/V)t} \tag{5-2}$$

where G = pollutant release rate (g/hr) and all other nomenclature remains as defined above. The functions described in Equations 5-1 and 5-2 are taken into account in the methods for calculating room air concentrations presented in Section 5.3.*

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*Note that these equations do not internalize consideration of various processes that may tend to remove contaminants from indoor air (i.e., "extinction" factors such as adsorption, absorption, or chemical transformation). As a result, its application will result in considerable overestimation of contaminant concentrations when such processes are in effect. If data from which extinction coefficients can be calculated are available for contaminants under evaluation, such coefficients should be integrated into equations 5-1 and 5-2 to allow development of more accurate concentration estimates.

(2) Gravitational settling. The importance of gravitational settling as a removal mechanism depends upon the size range of particulates released to air and the rate of ventilation in the room. Settling occurs at a velocity related to particle size and becomes significant for all particles of 5 μm or larger (Hanna and Hosker 1980). However, because ventilation usually limits indoor air contaminant residence time to less than 2.5 hours, only particles with a relatively high settling velocity are removed by this mechanism at a significant rate in the occupational setting.

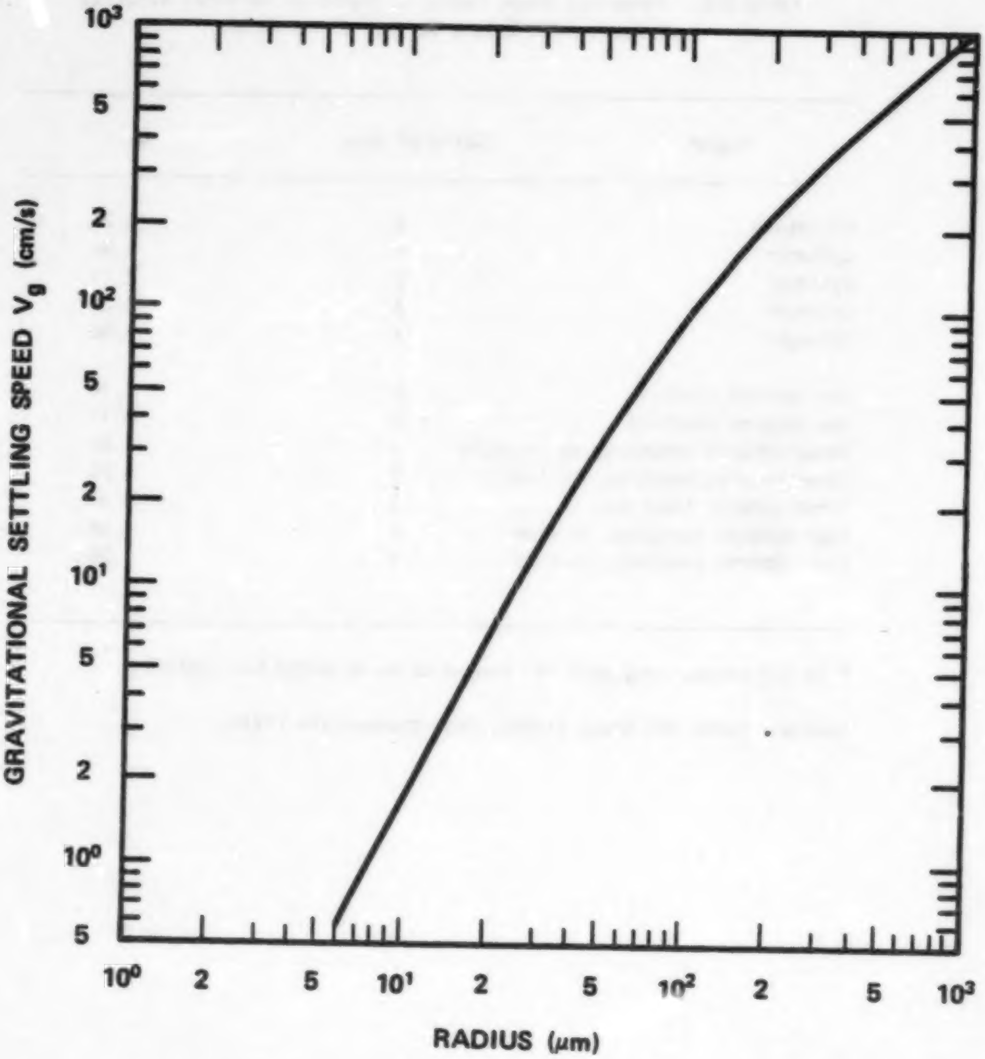
Note that gaseous pollutants can also adsorb to airborne particulates, resulting in their removal from the air phase due to gravitational settling. The rate of removal of gaseous contaminants by this mechanism is a function of particle quantity and adsorptive surface area per volume of air; particle settling rates; and contaminant-specific adsorption and desorption coefficients.

Particle settling velocities are a function not only of particle size, but also of particle shape, density, and orientation to the vertical direction of travel. Figure 5-1 presents settling velocities of spherical particles of 5 μm or larger, assuming particle density of 5 gm/cm. Estimates of settling velocity for particles of density other than 5 gm/cm^2 can be made by multiplying the velocity obtained from Figure 5-1 by the ratio: subject particle density ÷ 5 gm/cm. Settling velocities of nonspherical particles can be obtained by dividing the settling velocity of a particle of equivalent radius obtained from Figure 5-1 by the dynamical shape factor presented in Table 5-2. The radius equivalent of a nonspherical particle is obtained from the equation:

$$\text{radius equivalent} = [3 \times (\text{subject particle volume})/4\pi]^{1/3} \qquad (5\text{-}3)$$

Settling velocities for fibers are presented in Figure 5-2.

In practice, gravitational settling is usually moderated to some extent by turbulent or rising convective currents created by room activity or ventilation. Such convective currents can counteract gravitational settling, and reverse deposition to dry surfaces through resuspension. The effect of resuspension on room air concentration has been widely studied (USEPA 1983). Table 5-3 presents the ratio of room air concentration (gm/m^3) to surface concentration (gm/m^2), due to resuspension from various workplace activities. (Data in this table were compiled by Sehmel (1980) from the various sources indicated.) As the data in this table indicate, resuspension of deposited particulate contaminants must be considered an additional source of airborne



Source: Engleman 1968, as presented by Hanna and Hosker 1980.

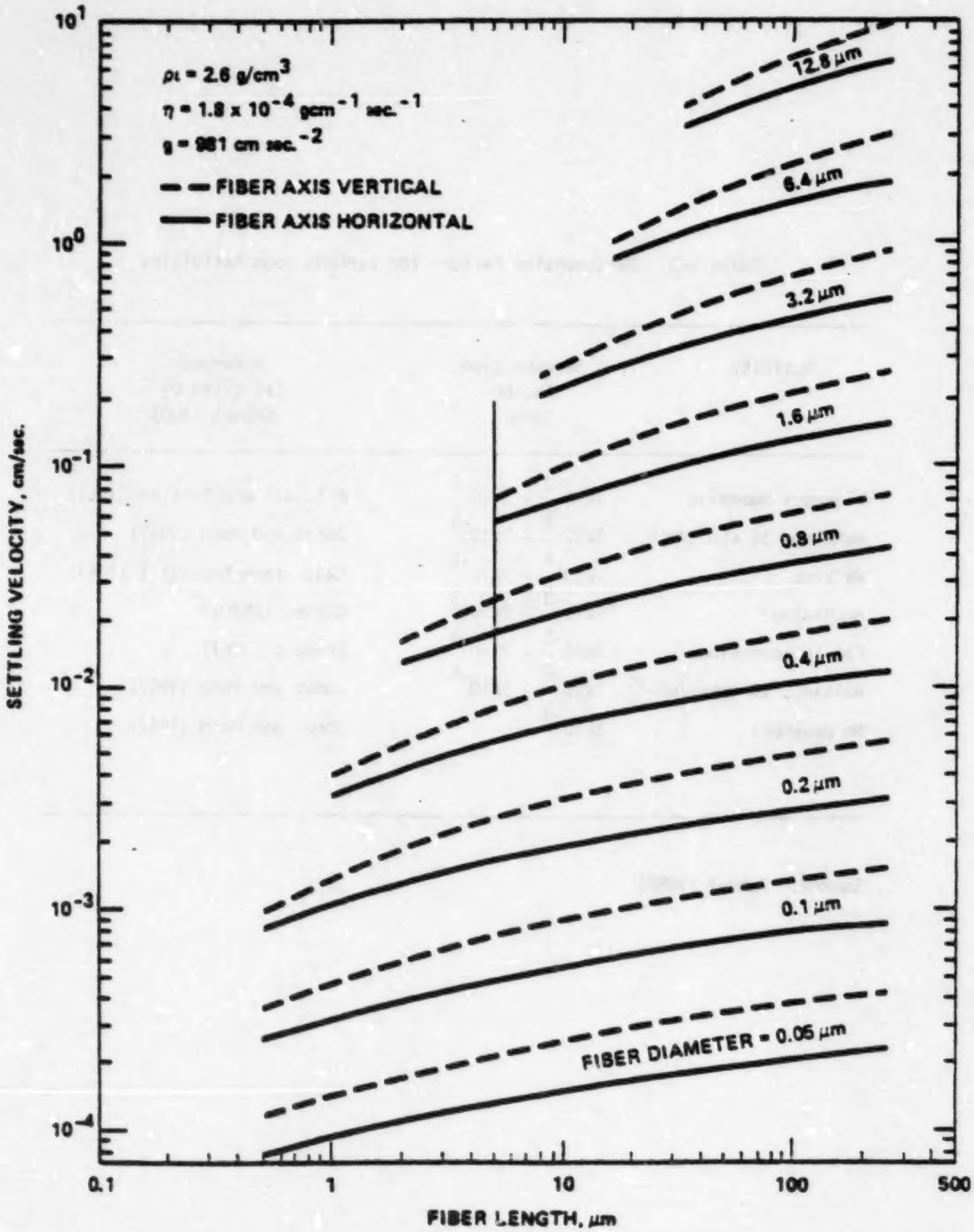
Figure 5-1. Gravational Settling Speeds for Particles with Density 5 gm/cm^3 Near the Earth's Surface

Table 5-2. Dynamical Shape Factor α (Ratio of Terminal Velocity of Equivalent Sphere to That of Particle)

Shape[a]	Ratio of axes	α
Ellipsoid	4	1.28
Cylinder	1	1.06
Cylinder	2	1.14
Cylinder	3	1.24
Cylinder	4	1.32
Two spheres touching	2	1.10
Two spheres touching	2	1.17
Three spheres touching, as triangle	-	1.20
Three spheres touching, in line	3	1.34
Three spheres touching, in line	3	1.40
Four spheres touching, in line	4	1.58
Four spheres touching, in line	4	1.56

[a] In all cases, long axis is assumed to be oriented horizontally.

Source: Hanna and Hoska (1980), from Chamberlain (1975).



Source: Sawyer and Spooner (1978).

Figure 5-2. Theoretical Settling Velocities of Fibers

Table 5-3. Resuspension Factors for Various Room Activities

Activity	Resuspension factor (g/m)	Reference (as cited by Sehmel 1980)
Vigorous sweeping	$1\times10^{-2} - 3\times10^{-2}$	Mitchell and Eustler (1967)
Walking, 36 steps/min	$5\times10^{-6} - 5\times10^{-5}$	Jones and Pond (1967)
Walking	$1\times10^{-4} - 1\times10^{-2}$	Calc. from Brunshill (1967)
Machining	$1\times10^{-3} - 7\times10^{-3}$	Carter (1970)
Fan in operation	$3\times10^{-5} - 2\times10^{-4}$	Stewart (1967)
Walking, 14 steps/min	$1\times10^{-6} - 1\times10^{-5}$	Jones and Pond (1967)
No movement	2×10^{-8}	Jones and Pond (1967)

Source: Sehmel (1980).

pollutants in the occupational settling. Concentrations of particulate pollutants in room air indicated in Table 5-3 apparently represent those resulting from the net particle movement due to the processes of settling and resuspension.

(3) Chemical degradation. Chemical degradation is of importance in the occupational setting only for those contaminants known to be relatively reactive. Again, because the room air residence time interval between pollutant release and removal via ventilation is usually limited, (e.g., usually less than 2.5 hours (Versar 1984b)), only those chemical reactions that occur rapidly can be expected to affect room air concentrations.

The most important reactions of organic compounds in the atmosphere are with the hydroxyl radical and with ozone (Hendry and Kenly 1979). A third process that has been shown to be important in the indoor setting is that of rapid degeneration of reactive pollutants on contact with typical indoor surfaces and materials, (Sutton, Nodolf, and Makino 1976, Meyer 1983, as reviewed by Versar 1984b).

Unfortunately, only limited data are available regarding the rates of these reactions in indoor air. Rates for ozonation and reaction with the hydroxyl radical in the atmosphere are available for many compounds from several sources; their application to the indoor setting is uncertain because of the differences in air flow, temperature, humidity, availability of ozone or OH, and availability of sunlight, between the indoor and outdoor air environments.

Estimated values or methods for estimating contaminant atmospheric half-lives based on chemical reaction rates are presented by Hendry and Kenly (1979), Lyman Reehl and Rosenblatt (1982); and Versar (1980).

5.1.3 Outdoor Airborne Contaminant Fate Processes

Those fate processes that are significant in transporting or removing air contaminants in the indoor occupational setting (as outlined in the foregoing subsections) are also the mechanisms most significant in the outdoor occupational environment. Again, convective removal is usually the predominant mechanism limiting residence time of pollutants in outdoor workplace air; removal via gravitational settling or chemical degradation can be considered significant only for contaminants with high particle density or those that are highly reactive in the atmosphere. Diffusion is not usually a significant transport mechanism in the outdoor air environment because of the infrequency and short duration of static air conditions. The manner in which convective currents affect air contaminant movement within and removal from the outdoor workplace is described in detail in Section 5.3.

5.2 Estimating Air Concentrations in the Indoor Occupational Setting

Chemical releases to indoor workplace air may contribute to occupational inhalation exposure by increasing gaseous contaminant air levels and by introducing respirable particulates into the air. The contaminant air concentrations resulting from industrial, trade, and consumer use releases must be estimated when personal or workplace monitoring data are not available. This section (see Table 5-4) presents theoretical algorithms from Berman (1982) that can be used to predict contaminant concentrations in indoor occupational settings. These concentration algorithms complement the algorithms presented in Section 4 for estimating release rates associated with industrial worker activities. For all industrial worker activities associated with significant contaminant releases to air (other than those for which saturation levels of contaminants in air are attained), the predicted contaminant concentrations in workplace air associated with the activity are directly proportional to the contaminant release rates estimated to occur during the activity.

The concentration algorithms in Table 5-4 are valid for use only within a simplified estimation framework that has the following features:

1. An indoor occupational setting includes hangars or shelters that are relatively isolated from conditions of the outdoor climate. See Section 5.3 for predicting contaminant concentrations for releases to outdoor occupational settings. See Volume 2 of this series (Freed et al. 1985) for predicting contaminant concentrations for releases to ambient air.

2. Contaminant concentrations are predicted as average room-wide air concentrations rather than concentrations in the immediate vicinity of the release source. Actual contaminant air concentrations near the release source, which the worker performing the activity or residing in the vicinity of release may inhale, can only be quantified from personal monitoring.

3. Of the three mechanisms for removing airborne contaminants from indoor air (ventilation, chemical degradation, and gravitational settling), ventilation is the only process that is accounted for in calculating room air contaminant concentrations (see Section 5.1).

Table 5-4. Occupational Indoor Air Contaminant Concentration Estimation Algorithms

Industrial activity	Expression for estimating contaminant air concentration	Comments
Drumming of liquids	$C = \frac{(1.8 \times 10^5)(T)(\Sigma G)}{(MW)(m)(Q)}$	Estimate G for each release source using expression (4-1) or (4-3).
Bagging and drumming of solids	------	Expression has not been developud due to lack of empirical data. Limited monitoring data for airborne particulate concentrations associated with solids handling were obtained from Berman (1982).
Cleaning of process equipment	Purging $C = \frac{(1.8 \times 10^5)(T)(\Sigma G)}{(MW)(m)(Q)}$	Estimate G for each release source using expression (4-1) or (4-3) with f=1. The vapor generated during purging is assumed to be saturated because equipment frequently is heated to facilitate purging of otherwise viscous residues.
	Opening $C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(m)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5). Use m = 0.1 in concentration expression to account for the nonsteady state nature of the contaminant release associated with opening process components. Using a diminished mixing coefficient simulates a nonsteady state system in which poor mixing of ventilation air with airborne contaminants results in contaminant air concentrations higher than those in a steady state, well-mixed system.
	Water washing --------	Significant contaminant release does not occur during water washing of process equipment. Residual contaminant material enters solution or suspension as water is added to the open compartment. Contaminant releases occur during purging and opening of process equipment prior to washing.

Table 5-4. (Continued)

Industrial activity	Expression for estimating contaminant air concentration	Comments
Solvent rinsing	$C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(K)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5). Use K = 0.1 in the concentration expression to account for the nonsteady nature of the contaminant release associated with solvent rinsing of process equipment (see comments for opening of process equipment). Assumes that the solvent does no boil during the rinsing operation (in some cases, the equipment is heated to increase the solubility of residue). This assumption is reasonable since vapors generated from a boiling solvent would pose a potentially greater hazard than that associated with vapor from residual material. The concentration estimated using this expression is a reasonable upper limit concentration resulting from releases associated with this operation.
Steam cleaning	$C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(K)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5). The concentration estimated using this expression is a reasonable upper limit concentration resulting from releases associated with this operation. However, concentrations likely will be smaller if it is assumed that steam cleaning follows other cleaning measures (during which initial significant releases of contaminant occur) and that volatile components in the residue not removed by the steam cleaning are minimal.
Shoveling and scraping:		
External cleaning	$C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(K)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5). The concentration estimated using this expression is a reasonable upper limit concentration resulting from releases associated with this operation. Use K = 0.1 in the concentration expression to account for the nonsteady state nature of the contaminant release associated with external cleaning of process components (see comments for opening of process equipment.)

Table 5-4. (Continued)

Industrial activity	Expression for estimating contaminant air concentration	Comments
	Shoveling and scraping: Internal cleaning $C = \frac{(P^\circ)(MW)(f)}{(R)(T)}$	A release rate does not need to be estimated here because it is assumed that the saturation concentration is a reasonable upper limit. The saturation concentration corresponds to the concentration when the partial pressure of the gas above the liquid is the pure vapor pressure of the substance; thus, f = 1 in this expression. The saturation concentration is a reasonable upper limit if it is assumed that ventilation is poor.
Maintenance	External ---------	Contaminant releases associated with external maintenance of process components are not likely to be significant if it is assumed that seals are not broken during the maintenance operation. Releases from fugitive sources may occur during these activities.
	Via access and other openings $C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(K)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5). The concentration estimated using this expression is a reasonable upper limit concentration resulting from releases associated with this operation. This equation assumes that maintenance via access portals or other openings requires breaking of lines or opening of process equipment, and it also applies to changing filters. However, when estimating G, substitute the surface area of the filter for the surface area of the aperture for parameter "A."
	Entering process enclosures $C = \frac{(P^\circ)(MW)(f)}{(R)(T)}$	This is an estimation of the reasonable upper limit (saturation) concentration. See comments for "Internal shoveling and scraping" under "Cleaning of process equipment"; here also, f = 1. Due to a large contaminated surface area in the vessel (i.e., the surface area of interior walls of the vessel) and poor ventilation in the vessel, it was assumed that saturation would be attained.

Table 5-4. (Continued)

Industrial activity	Expression for estimating contaminant air concentration	Comments
Sampling and analysis	$C = \frac{(1.7 \times 10^5)(T)(\Sigma G)}{(MW)(K)(Q)}$	Estimate G for each release source using expression (4-4) or (4-5) if contaminant releases are controlled by volatilization, or expression (4-8) if contaminant releases are controlled by displacement of saturated vapor. The relative contributions to contaminant release from volatilization and displacement must be assessed using expressions (4-4) (or (4-5)) and (4-8) with site-specific values of input parameters. Use K = 0.1 in concentration expression to account for the nonsteady state nature of contaminant release from sampling and analysis.

Source: Berman (1982).

Legend for Table 5-4

C	**Average steady state concentration of contaminant in workplace air, parts per million (ppm).**
G	**Constant steady state release rate of contaminant to air, grams per second (g/sec).**
$\sum G$	**Summation of contaminant release rate G over all sources of a specific type (e.g., drumming operations) present in the workplace, grams per second (g/sec).**
Q	**Ventilation rate in the workplace, cubic feet per minute (ft^3/min).**
m	**A mixing factor that quantifies the effectiveness of ventilation air in removing airborne contaminants from the workplace, dimensionless.**
MW	**Molecular mass of contaminant, grams per gram-mole (g/gmole).**
P°	**Vapor pressure of the pure contaminant, atmospheres (atm).**
T	**Absolute temperature, degrees Kelvin (K).**
R	**Universal gas constant, 82.05 $\frac{(\text{cubic centimeters})(\text{atmospheres})}{(\text{gram-mole})\ (\text{degrees Kelvin})}$**
f*	**A saturation factor that quantifies the extent to which the saturation concentration of the contaminant in workplace air is attained, dimensionless.**

*** Berman (1982) presented the saturation factor f to quantify the extent to which saturation is attained for contaminant releases to workplace air during drumming of liquids; however, it can be used to quantify the degree of saturation attained for contaminant releases to air from any source or during any activity. If f is equal to 1, then the partial pressure of airborne contaminant vapor is equivalent to the vapor pressure of the pure contaminant liquid at the temperature of the operation or activity; the workplace air is then saturated with contaminant vapor.**

4. Predicted contaminant concentrations in room air are steady state concentrations. The steady state concentration of a contaminant in indoor air is that concentration at which the rates of contaminant removal by ventilation and contaminant release by the source equilibrate and remain constant. The contaminant concentration is directly proportional to release rate and inversely proportional to ventilation rate; when the rates of contaminant generation and removal equilibrate, then the contaminant air concentration remains constant at an average steady state value.

   Nonsteady state conditions are those in which the rate of contaminant generation or removal varies with time (e.g., a brief, intermittent contaminant release that introduces a finite mass of contaminant into the air). Theoretical expressions for predicting concentrations at selected spatial and temporal intervals have not been developed. For nonsteady state cases, the steady state models were modified by Berman (1982) to incorporate a diminished mixing factor m (which measures the effectiveness of ventilation air in removing airborne contamination). The m factor is assumed to be its minimum value of 0.1, which corresponds to poor mixing and thus higher contaminant air concentrations than those estimated for steady state conditions.

   For situations in which a worker performs an activity inside of a process enclosure, the source of contaminant release is assumed to be in excess, and saturation concentration is assumed to be attained.

5. To compute predicted values of contaminant air concentrations, values of input parameters should be determined on a case-by-case basis using site-specific data. Required input data include physical and chemical properties of the contaminant; characteristics of the process equipment, operation, and activity; and characteristics of ventilation in the area where the operation or activity is performed. Berman (1982) presents ranges, typical, and worst-case values of input parameters which can be used to determine screening values of contaminant release rates and resulting air concentrations.

6. Accurate estimates of air concentrations must account for the relationship between the time when the release occurs and the worker's exposure period. For example, if it is assumed that a worker conducts an activity in which a contaminant is released at a constant rate into workplace air for a fixed duration, then the average contaminant concentration that may be inhaled by the worker can be determined only if the duration that the worker remains in the release area is known. This average concentration

does not necessarily correspond with the steady state contaminant concentration. The average contaminant concentration that a worker may inhale will be greater if the worker remains in the release area for only one hour following release as opposed to eight hours following release, since ventilation dilution effects become more predominant in the latter case. Time-weighted average (TWA) concentrations may have to be computed to obtain accurate estimates. Just as when estimating contaminant release rates, the user should follow an additional step before estimating the source strength to which a person in an occupational setting is exposed. This step involves integrating predicted contaminant air concentrations with site-specific data on the nature of release and worker procedures.

5.3 Estimating Air Concentrations in the Outdoor Occupational Setting

Dispersion modeling is commonly used to estimate concentrations of air pollutants in the ambient air. Typically a Gaussian model is used to represent transport and dispersion of emissions as a function of release specifications (e.g., stack height, exhaust temperature, stack diameter, or flow rate) and meteorological conditions such as wind speed, wind direction, atmospheric stability and mixing height. Most Gaussian modeling is applied to receptors in the range of 200 m to 50 km.

Modeling is generally used to estimate concentrations off the property boundary of a source; for those applications, exposures to the general public are evaluated. However, workers at the source can be exposed to concentrations substantially higher than those offsite. As mentioned above, Gaussian modeling is not generally considered to be appropriate within 200 m of a source because of the statistical assumptions inherent in this approach regarding the distribution of concentration within a plume.

Occupational exposures are usually best characterized by monitoring, because of the uncertainty in predicting concentrations in the short range. Whenever workers may be exposed to high risk associated with air pollutants, it is recommended that a monitoring plan be developed to characterize these exposures. However, for any given situation, it may be difficult to know whether monitoring is needed. Whether personal sampling or workplace monitoring is performed, the cost of these programs can be high. The following approach provides conservative screening-level estimates of long-term occupational exposures to on-site (outdoor) workplace air pollutants.

There are numerous reasons why it is not possible to accurately estimate concentrations in the short range (defined for the purpose of this task to be 0 to 200 m from a source). Highly variable concentrations can be encountered from complex flows around obstructions, and plume dimensions are relatively small in relation to turbulent eddies that disperse the pollutants. The problem is much too complicated to expect predictions that are within a factor of 2 to 3, as would typically be the case for long-term averages further downwind of a source, e.g., 500 to 2000 m. This approach yields conservative assumptions (i.e., overestimates of expected impacts) because of these uncertainties. In this manner, one should be able to estimate long-term concentrations with reasonable confidence that the values will not exceed actual long-term average concentrations. If these estimates suggest unacceptable risk, personal monitoring would be the logical follow-up option to complete the analysis.

There are basically three types of releases that could be expected in occupational settings: stack releases, vent releases, and groundlevel releases associated with waste piles, disposal, etc. Estimates are provided for releases from the last two categories, i.e. vent and ground level releases. Stack releases are not considered because maximum impacts from elevated releases generally occur off the property boundary and are thus best considered as an ambient exposure problem. These emissions should be evaluated by standard modeling practices. For stack releases, we are referring to release points that are not expected to be entrained in building wakes for any routine meteorological conditions. For example, stack heights of 2 1/2 times the height of nearby obstructions would typically be considered elevated releases under all conditions. If there is any question regarding elevated release versus entrained release, it is recommended that the vent release equation (see Section 5.3.2) be used to characterize ambient exposures at the workplace.

5.3.1 Ground Level Releases

It is difficult to characterize the horizontal and vertical growth of a plume within the first 200 m from a source. However, the most feasible approach is to make conservative, simplifying assumptions, and for screening estimates, the following is assumed:

1. Annual average estimates are made.
2. An average wind speed of 2 m/sec is assumed to conservatively represent annual average wind speed.
3. It is assumed that wind direction flow is uniform around the compass. However, in order to develop conservative estimation, frequency of flow towards the affected receptor is assumed to be 20 percent.

4. It is assumed that all releases can be represented by a sector average approach, i.e., the horizontal distribution of concentration along each arc is uniform within each sector.

5. The vertical dimension of the plume is conservatively bounded at 2 m for all receptors from 0 to 200 m. In addition, it is assumed that uniform concentrations exist along the vertical plane for each downwind distance evaluated.

6. Concentrations displayed below are normalized to a release of 1 gm/sec, i.e., indicated values, when multiplied by actual emission rates in gm/sec, will yield estimates of actual ambient concentrations.

7. It is assumed that all emissions occur from one point. The equation for this model is as follows:

$$C = \frac{(1.0 \times 10^6 \text{ ug/gm})\ (0.20)}{(\sin 22.5°)\ (R)\ (H)\ (u)} \qquad (5\text{-}4)$$

where

C = concentration (ug/m^3) normalized to an emission rate of 1 gm/sec
H = height into which plume is uniformly mixed (m)
R = downwind distance from source (m)
u = annual average wind speed (m/sec) = 2 m/sec.

Estimated _normalized_ concentrations are as follows:

Downwind Distance From Source (m)	Predicted Annual Average Concentration Normalized to Release of 1 gm/sec (ug/m^3)
10	13,066
20	6,532
30	4,355
40	3,266
50	2,614
60	2,178
70	1,866
80	1,634
90	1,451
100	1,306

As stated above, these estimated normalized annual average concentrations with distance from the release source can be multiplied by the actual emission rate to estimate the outdoor workplace air concentrations resulting from the release. These estimates are considered conservative mainly because of the assumption that the vertical extent of the plume is limited to 2 m. It is implied in this assumption that once the plume reaches the breathing level (i.e., 2 m), further growth is zero. It is necessary to be this conservative because of the great uncertainty in accurately characterizing this term. The annual average wind speed of 2 m/sec and a frequency factor of 20 percent flow towards affected receptors are also considered to be conservative assumptions.

5.3.2 Vent Releases

For releases from rooftop vents or low-level stacks located adjacent to or on buildings, building downwash of the pollutants is an important factor for two main reasons. First, effluents are rapidly brought to ground level rather than being directly transported offsite; this can produce localized maximum concentrations. Second, the vigorous turbulent mixing in the lee of the building can produce substantial initial dispersion to reduce concentrations.

The cavity zone in the lee of an obstruction can extend 2 to 3 building heights downwind (Hanna, Briggs, and Hosker 1982). The turbulent wake of a building, on the other hand, can be distinguished 5 to 20 building heights downwind (Slade 1968). Therefore, there are three zones to evaluate when considering impacts, i.e., cavity zone, wake zone, and the zone outside the wake zone for which routine modeling procedures are generally applied. For the purposes of occupational exposure screening, only estimates for the cavity zone will be made. This limitation is made to simplify the analysis, and because maximum impacts would be expected in this zone.

Although gradients in concentration have been observed adjacent to release points in a cavity zone (Slade 1968), for all practical purposes, it is reasonable to assume that effluents are rapidly and thorougly mixed within the cavity zone. If this assumption is made, the following equation can be used to estimate concentrations within the cavity zone (derived from Hanna 1982):

$$C = \frac{K_c\ (1.0 \times 10^6)\ (\mathrm{freq})}{A\ \bar{u}} \qquad (5\text{-}5)$$

where

C = concentration (ug/m^3) normalized to a release rate of 1 gm/sec
K_c = dimensionless concentration coefficient
A = cross-sectional area of the building (m^2)
$\bar{u}$ = average wind speed at rooftop (m/sec)
freq = frequency of flow towards affected receptor.

For conservative estimates, it was assumed that $\bar{u}$ = 3 m/sec and the frequency of flow toward the quadrant being evaluated is 75 percent (i.e., 0.75). The coefficient K_c has been reported to range from 0.2 to 2.0. The conservative extreme of 2.0 was used for these calculations. The following estimates were made based on this model:

Building Area (m^2)	Predicted Concentration Normalized to Release of 1 gram/sec (ug/m^3)
100	5000
300	1667
500	1000
750	667
1000	500
1500	333
3000	167
5000	100

The above estimates are assumed to apply within the cavity zone and to apply out to a distance of 2 x A. It is stressed that the estimates provided in this section are rough, screening-level estimates. Actual annual average concentrations would be expected to be lower for most sites. However, depending on site specifics, it is possible that actual concentrations could be higher than these predictions. Some typical onsite factors that can affect the initial dilution of the plumes released from the ground level sources are:

- Physical dimensions of the area or line source.
- Surface roughness and mixing due to the wind flow being obstructed by storage piles, resulting in greater dilution of the plume.
- Thermal convection due to heat releases or losses from the facility, also aiding in the diffusion.

- The alignment of the sources in relationship to the wind, such that the total concentration is enhanced.

Therefore, judgment should be used when the results are interpreted on a case-by-case basis.

6. EXPOSED POPULATIONS ANALYSIS

Studies of populations exposed in the occupational environment comprise the following elements:

- Identification of exposed populations
- Enumeration of detailed subpopulations
- Characterizing populations with respect to physiologic-dependant parameters
- Determining the frequency and duration of a population's exposure

Exposed population identification involves the categorical determination of worker populations potentially exposed in a given workplace situation. Once broadly defined in the population identification step, individuals in discrete exposed subpopulations are quantified (counted) in the population enumeration analysis. In practice, population identification and enumeration, both of which are addressed in Section 6.1, are often carried out concurrently, with the same data sources providing requisite input for both analyses. Characterization of exposed populations, briefly discussed in Section 6.2, follows the identification and enumeration steps. It involves the evaluation of worker age and sex factors which influence various physiologic-related parameters, such as inhalation rate and skin surface area, and which are necessary to calculate the degree of exposure experienced per exposure event. Exposed populations analysis concludes with determination of factors that define the duration of exposure events and event frequency. This is discussed in Section 6.3.

6.1 Identification and Enumeration of Exposed Populations

Identification of exposed populations requires a knowledge of the spatial and temporal concentration gradients in the workplace and the activity patterns of the potentially exposed workers. The purpose of population identification should be borne in mind at this point in the occupational exposure assessment. Those workers identified as exposed populations will subsequently be enumerated. The form of worker population data should thus be considered during this step; 4-digit SIC designations and specific occupations (job titles) are the most common form by which workers are enumerated. Estimates of occupationally exposed populations may also be based on site-specific and process-specific employment data.

In occupational exposure assessments, two types of population identification and enumeration data will be required: generic data and specific data. Generic data include data which identify and/or enumerate potentially exposed populations by SIC code or by occupation and industry. Specific data identify workers who are involved in exposure-related activities. The determination of worker activities conducted at facilities being evaluated (see Section 4) often provides the most critical input to the identification and enumeration of exposed populations. When accessible, worker activity data can supply detailed information on categories of workers conducting specific activities in the workplace that will cause exposure, as well as on the number of individuals conducting such activities at individual facilities or facility types. The following sections address each of these population identification/enumeration approaches.

6.1.1 Generic Identification and Enumeration Data

(1) Populations identified and enumerated by SIC code. The industries producing, processing, and using a chemical substance are often identified by 4-digit SIC designations. Many of the data sources discussed in Section 2 of this report are based on the SIC reporting system. However, identification and enumeration by SIC code provide only a broad-scale determination of potentially exposed populations because, in reality, only a portion of the total employment may be affected.

Populations exposed in the workplace can also be identified through monitoring data. The OSHA surveys and NIOSH/NOHS data discussed in Section 3 are based on 4-digit SIC codes. Monitoring data provide direct identification of exposed populations. OSHA monitoring data also identify exposed workers by specific job title, often enabling a more precise enumeration of the affected group.

(2) Populations identified and enumerated by occupation and industry. A method of worker identification and enumeration that provides greater resolution than the SIC code approach is the use of detailed occupation and industry information (job titles). This method entails systematically following a chemical substance through commerce, from production to retail sale, and listing the industries and occupations coming into contact with the substance. The Industry-Occupation (I-O) matrix directory in Dixon et al. (1985) can be used as a guide in this procedure. In addition, information published by the Bureau of Labor Statistics (BLS 1981) and the Bureau of Census (1984) also provides data highly useful in identifying and enumerating exposed worker populations. Also, monitoring data may list exposed populations by job title.

6.1.2 Specific Identification and Enumeration Data

The best data for identification and enumeration of exposed occupational populations specify populations by particular activities conducted in the workplace. Such data constitute critical input to the successful development of an occupational exposure assessment, because only by determining the relationship between workplace activities and workplace contaminants can the degree of exposure be quantified with any confidence. Unfortunately, such data are limited, and there exists no single comprehensive data base detailing exposure related worker activities. Two general sources of these data do exist, however. As described in Section 4, worker activities that lead to exposure can be considered to fall into the following generalized categories:

- Drumming of liquids
- Handling of bulk solids
- Equipment cleaning
- Equipment maintenance
- Sampling and analysis

Based on process mass balance analysis, the expected occurrence of these worker activities can be estimated for specific processes and varying process throughputs. Often the mass balance analysis, therefore, can supply requisite data for the identification and enumeration of exposed worker categories to support an activity-specific exposure analysis.

Examination of a random sample of Premanufacturing Notices (PMNs) conducted in 1982 also identified reported worker activity categories that can result in exposure. The full list of such activities identified during the PMN review effort included:

- Sampling for quality control
- Cleanup of components
- Waste disposal
- Sampling and analysis
- Materials transfer
- Manufacture, processing, and use (general)

As review of this list reveals, PMN data indicate that practically all categories of worker activities could potentially lead to exposure. This realization underlines the fact that a process mass balance approach to occupational exposure assessment will often be required to discern the types of exposure related worker activities that pertain to the particular industries and processes under evaluation.

6.2 Population Characterization

Population characterization involves determining the age and sex distribution of the exposed worker population(s). Age and sex influence the average ventilation rate, the rate of food and water intake, and the body area subject to dermal exposure, any of which can affect the level of exposure actually experienced. In addition, population characterization includes determining those groups within the exposed population which, because of the specific health effects of some pollutants, would experience a higher risk than the average population as a result of a given level of exposure. Indeed, the health effects of the contaminants under evaluation will often dictate the need for population characterization. For occupational exposure assessments, women of childbearing age will often constitute the high risk group of concern. While most studies will consider only the exposed population as a whole and not disaggregate discrete high risk subpopulations, in certain cases such detailed population analysis may be warranted. For example, if a chemical substance is determined to be teratogenic, enumeration of women of childbearing age would be required.

6.3 Frequency and Duration of Occupational Exposure

The frequency and duration of exposure to a chemical substance are important components of the final calculation of exposure. Frequency and duration are separate elements, but are so closely related they will be treated together in the following discussion.

The frequency of exposure refers to how often an activity leading to exposure occurs. The duration of occupational exposure can be defined in two ways: (1) the discrete period of time during which an incidence of exposure occurs, and (2) the length of time the exposure-related job is held by an individual. The frequency and duration of occupational exposure is related to the nature of the process, activity, or occupation in which the worker is engaged; individual work patterns, not easily generalized, may also affect these parameters. Section 6.3.1 contains the available data on frequency and duration of occupational exposure. Section 6.3.2 deals with the concept of "worklife," the number of years a person is employed.

6.3.1 Frequency and Duration

Ideally, the frequency and duration of exposure in industry should be related to activity or process data. The nature of a process (i.e., whether batch or continuous) and the intermittency of activities, (e.g., materials transfer and sampling), are important determinants of exposure frequency and duration (see Section 4). Such factors should be taken into account when monitoring strategies are devised, so that requisite data will be obtained for use in developing an exposure assessment or in refining a previously developed assessment.

In cases where worker exposure is continuous, the use of general frequency and duration data is indicated. The frequency is therefore constant at once per day or week, and the duration is the number of hours worked per day or week. Table 6-1 lists the average number of hours worked weekly by production employees in the various manufacturing industries in 1979. These data can be used in lieu of assuming a standard 40-hour workweek.

The data presented in Table 6-1 can be further refined by two additional data elements:

Table 6-1. Average Weekly Hours of Production Workers on Manufacturing Payrolls in 1979

Title	SIC	Hours worked
Durable goods	-	40.8
Lumber and wood products	24	39.5
Furniture and fixtures	25	38.6
Stone, clay, and glass	32	41.5
Primary metal products	33	41.4
Fabricated metal products	34	40.8
Machinery, except electrical	35	41.8
Electric and electronic equipment	36	40.3
Transportation equipment	37	41.2
Instruments and related products	38	40.8
Miscellaneous manufacturing industires	39	38.9
Non-durable goods	-	39.3
Food and kindred products	20	39.9
Tobacco manufacture	21	38.0
Textile mill products	22	40.3
Apparel and other textile products	23	35.2
Paper and allied products	26	42.6
Printing and publishing	27	37.5
Chemicals and allied products	28	41.8
Petroleum and coal products	29	43.8
Rubber and miscellaneous plastic products	30	40.5
Leather and leather products	31	36.5

Source: BLS 1980.

- A certain amount of paid time on the job may be spent in breaks for meals or other nonwork activities. Labor laws can be consulted to determine mandated scheduling and duration of breaks, etc. This time can be subtracted from the durations presented in Table 6-1.

- Few persons actually work 5 days a week, 52 weeks per year. The number of operating days for a plant is a better indicator of days worked per year. Vacation and lost work days (due to illness or injury) can also be estimated. A total absenteeism rate of 3.5 hours per hundred hours worked (BLS 1980) can be used as a correction factor.

The preceding discussion is geared toward frequency and duration of production workers' exposure. Data obtained as described in Sections 2 and 3 should indicate whether nonproduction workers are continuously exposed, in which case Table 6-2 provides the best available duration data. Intermittent exposure of workers (such as those walking through the plant area) should be approximated. No generic data are currently available to aid in this estimation; should those populations be identified as possibly receiving significant exposure, a duration value such as one hour per day might be used as a plausible worst-case estimate. Table 6-2 lists available data on hours worked in nonmanufacturing industry such as wholesale trade and commercial use.

A factor to be considered in estimating the frequency and duration of exposure is the seasonal nature of some activities, although such seasonality may vary or be unimportant depending on the geographic focus of the exposure assessment. If the substance under assessment is, for example, a component of a garden fertilizer, retailers may only deal with it for six months of the year. The duration of a retailer's exposure to the garden fertilzer component would therefore be 30.7 hours per week for 24 weeks per year. Other seasonal activities include some agricultural services, construction, and amusement and recreation services.

Exposure frequency and duration data obtained from the previously mentioned random sample of PMNs (see Section 6.1.2) are presented in Table 6-3. It is not possible to correlate either production volume or chemical use with exposure frequency or duration, but some generalizations about activities can be made:

- Sampling activities can be assumed to last approximately 5 minutes per sample. Thus, from the PMN data presented in Table 6-3, it can be inferred that roughly 24 sampling events occur in a normal workday.

- Material transfers can be assumed to last approximately three to five minutes each. The total number of events per workday depends on the industry, as reflected in Table 6-3.

Table 6-2. Average Weekly Hours of Workers in Nonmanufacturing Industry in 1979

Occupation	Hours worked
Retail sales persons	30.7
Wholesale sales persons	38.8
Mining (production workers)	43.0
Construction workers	36.9
Transportation and public utilities	39.9
Finance, insurance, and real estate	36.3
Service workers (unspecified)	32.7

Source: BLS 1980.

Table 6-3. Frequency and Duration of Occupational Exposure for Specific Activities, Derived from a Random Sample of PMNs

Activity	Product	Production volume (kkg/yr)	Exposure duration and frequency	
			(hr/day)	(day/yr)
Sampling	Anti-rust additive	350,000	2	13-18
	Emulsifier	115,000	2	14-22
Cleaning	Anti-rust additive	350,000	1	13-18
	Pigment	12,250	2	5
		12,250	2	5
		12,000	2	8
	Emulsifier	115,000	1	14-22
	Miscellaneous	2,000	2	2
Transfer	Coating	150,000	1	150
		90,000	1	30
		4,540,000	1	150
		80,000	2	4
	Lube oil additives	430,000	8	250
		900,000	1	35
	Pigment	8,600	2	28
	Photographic component	50	0.5	1
		30	0.5-2.5	50-150
		11,000	2	150
	Emulsifier	500,000	1	200
	Surfactant	300,000	2	50
	Plastic	16,000	2	10
	Miscellaneous	4,000	1	20-40
		4,540,000	1	250
		70,000	1	5
		15,000	2	10
		10,000	8	6
		16,000	2	5

Table 6-3. (Continued)

Activity	Product	Production volume (kkg/yr)	Exposure duration and frequency	
			(hr/day)	(day/yr)
Disposal	Coating	400,000	1	260
		1,000,000	1	10
		350,000	<1	80
		250	8	8
		120,000	1	10
		125,000	1	252
	Automotive products	3,000,000	3	312
		27,200	3	300
	Surfactant	300,000	1	50
	Miscellaneous	50,000	6-8	24
		50,000	8	10
		1,400,000	1-8	1-10
		10,000	1	6
Manufacture	Coating	200,000	8	30
		400,000	8	260
		500,000	8	120
		100,000	3	30
		720,000	6	89
		1,000,000	1	10
		400,000	6	14
		33,000	6	7
		350,000	<1	80
		454	8	60
		250	8	8
		492,000	4	80
		3,585,000	8	250
		80,000	6	9
		50,000	8	15
		450,000	6	18
		120,000	1	10
		35,000	6	5
		125,000	8	252
		80,000	10	7
		500,000	8	15
		300,000	8	5
		450,000	8	120

Table 6-3. (Continued)

Activity	Product	Production volume (kkg/yr)	Exposure duration and frequency	
			(hr/day)	(day/yr)
	Electrodeposition chemicals	1,750,000	8	150
		1,000,000	5	4
		45,000	6	6
	Adhesives	1,500,000	8	22
		144,000	1-2	30
		2,000	1	40
		4,000,000	1	4-32
		1,500,000	8	100
		27,216	1	200
		4,540,000	8	77
	Pigment	300,000	6	7
		150,000	1	11
		4,500,000	1	150
	Photographic component	5,000	8	250
		5,000	8	250
		100,000	8	75-100
		30	8	2-6
		50	5	1
		908	1	20-35
	Emulsifier	45,000	1	10
		45,000	1	10
		200,000	8	140
	Automotive products	16,000	4	96
		3,000,000	1-4	312
		27,200	1-4	300
	Surfactant	1,600,000	6	7
		500,000	8	5

Table 6-3. (Continued)

Activity	Product	Production volume (kkg/yr)	Exposure duration and frequency	
			(hr/day)	(day/yr)
	Resin (unspecified)	300,000	8	200
		2,500	8	24
	Plastic	350,000	4	20
		4,540,000	4	50
	Miscellaneous	50,000	8	10
		300,000	8	100-200
		650,000	6	13
		1,400,000	3-8	62-250
		100,000	8	20
		110,000	5	20
		1,500	8	20-25
		25,000	8	50
		8,000	6	5
		14,000	3	36
		260,000	8	330
		4,540	2	10
		10,000	2	6
		4,000	8	2

- Cleaning operations generally last from one to two hours.

- Disposal exposures may range from less than one to eight hours in duration.

- The duration of manufacturing exposure depends on the nature of the process. Both batch and continuous manufacturing may result in eight hours of exposure per worker per day (i.e., continuous exposure during a full 8-hour shift); the number of operational days varies.

The generalizations above can be used to estimate frequency and duration of exposure. Alternatively, the assessor can consult Table 6-3 and choose the most applicable data, i.e., that matching the activity, product, or volume of the chemical being assessed. This approach should be used with care, since the data base is limited.

6.3.2 Worklife

Occupational exposure assessments of substances suspected to be carcinogenic or to have other latent effects often require an estimate of the length of employment in the exposure situation. It is not possible to estimate the period of time worked by any individual in a particular job or industry; it may range from a day to over 40 years. The best available data simply estimate the total number of years men and women work (see Table 6-4). These data can be used directly to project exposure if one assumes that an individual holds the same job for his or her entire life. It should be noted that "worklife expectancy" is declining for men; this is attributed to earlier retirement made possible by increased benefits and the second paycheck earned by a growing number of working women (Fullerton and Byrne 1976).

Table 6-4. Length of Working Life for Men and Women

Expectancy at birth in years	1940	1950	1960	1970
Men				
Life expectancy	61.2	65.5	66.8	69.6
Work expectancy	38.1	41.5	41.1	40.3
Nonwork expectancy	23.1	24.0	25.7	29.3
Women				
Life expectancy	65.7	71.0	73.1	74.7
Work expectancy	12.1	15.1	20.1	22.3
Nonwork expectancy	53.6	55.9	53.0	52.4
Women's worklife as a percent of men's worklife	31.6	36.3	48.6	57.3

Source: Fullerton and Byrne 1976

7. CALCULATING EXPOSURE

7.1 Introduction

Inhalation and dermal contact constitute the main routes of exposure in occupational settings, with inhalation exposure being the more common of the two. The subsections below present equations for calculating exposure via both of these routes. In addition, ingestion exposure can result from (1) inhalation of non-respirable contaminated particulates (see Section 2), (2) deposition in the mouth via hand-to-mouth contact, or (3) settling of airborne particles on the lips. This section, therefore, also addresses means of calculating exposure due to contaminant ingestion.

Calculation of exposure basically involves combining knowledge of the level of contamination of a given medium with consideration of the degree of worker contact with the medium. Thus, for non-occupational exposure assessments, this calculation takes into account not only contaminant concentrations but also pertinent inhalation rates, ingestion rates or area of skin exposed, and the frequency and duration of exposure events. However, in assessing occupational exposure, one should also consider the use of protective measures.

Although data quantifying contaminant concentrations in environmental media can generally be used directly to estimate exposure to receptors in most exposure assessment situations, this will not necessarily be the case in occupational analyses. Industry is well aware of many of the dangers posed by handling or processing chemical substances, and workers in industrial or commercial settings will often have the option or may be required to use protective equipment and/or clothing to reduce or eliminate their exposure to the substances with which they work. Thus, for any given occupational exposure assessment, the exposure reduction achievable through use of protective measures must be considered. Basically this analysis will involve addressing the following questions:

- What type of protective measures are used (e.g., protective equipment such as respirators or protective clothing)?
- What is the relationship between the length of time workers use the protective measure and the length of time they are in a contaminated environment within the workplace?
- What is the effectiveness of the protective measures in reducing the level of exposure experienced by the workers?

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Selection of protective equipment or clothing is often very situation-specific. Information describing protective equipment and clothing appropriate for specific types of exposure can be obtained from the literature and from industry sources. Appendix B presents a bibliography of literature sources on protective clothing (adapted from USEPA 1982). While the source materials listed in this appendix primarily pertain to pesticides, these references also supply a significant degree of insight into the types of protective measures generally available to industry. Direct industry contact may yield the best and most current information describing the types of protective clothing and equipment used in specific situations. The type of protective measure used will generally be a function of the type of exposure potential involved (i.e., inhalation, dermal contact, etc.), and the type of activities that are likely to bring workers into contact with toxic chemicals. The material from which the protective equipment or clothing is made will depend primarily on the physical/chemical properties of the materials to be handled.

Once the questions previously listed have been answered, data quantifying the degree of protection afforded by each pertinent protection measure can be used to estimate worker exposure. This is accomplished by adjusting (reducing) estimates of the amount of chemical with which workers are likely to come into contact by an amount equal to the degree of protection provided by each measure. If use of protective measures is voluntary rather than mandatory, the degree of actual use in the workplace may not be well documented. In such cases it will be beneficial to calculate a range of worker exposure reflecting both the exposure that results when no protective measures are taken as well as that which results when protective clothing and/or equipment is used throughout the exposure period.

The degree of protection provided by protective clothing, respirators, etc., can be factored into the exposure equations presented below as the protection factor (P). When empirical data on the efficiency of such devices are not available, it may be convenient to assume a generic protection factor of 0.1 to 0.01 to represent an assumed efficiency of 90 or 99 percent, respectively.

7.2 Inhalation Exposure

The standard equation for calculating inhalation exposure is as follows:

$$IHX = IR \times DU \times FQ \times C \times P \qquad (7\text{-}1)$$

where

IHX = inhalation exposure (mg/yr)
IR = inhalation rate (m^3/hr)
DU = duration of exposure event (hours)
FQ = frequency of exposure (events per year)
C = indoor air concentration of a given constituent (mg/m^3)
P = protection factor.

Inhalation rate (IR) is expressed in m^3/hr; values for different levels of activity are summarized in Table 7-1. The protection factor (P) accounts for the use of a respirator (see Section 7.1). The frequency and duration parameters are discussed in Section 6.

This equation can be modified for chemicals present in the air as particulates, to account for the partitioning of particles between the gastrointestinal tract and the lungs as a function of particle size. Total exposure to particulates calculated by Equation 7-1 can be differentiated into pulmonary exposure (IHX_p) and gastrointestinal exposure (IHX_G) using Equations 7-2 and 7-3, respectively. This partitioning of inhalation exposure is an option that may be worthwhile for chemicals whose effects depend on the mode of entry into the body.

$$IHX_p = IR \times DU \times FQ \times C \times RF \times P \tag{7-2}$$
$$IHX_G = IR \times DU \times FQ \times C \times NRF \times P \tag{7-3}$$

where

RF = respirable fraction, which is the weight fraction of all inhaled particles deposited in the pulmonary airspaces.

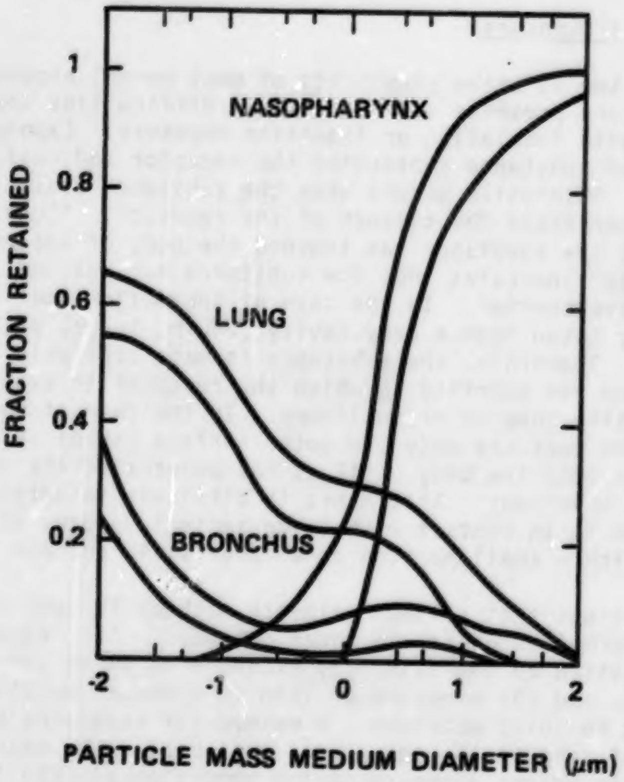
NRF = nonrespirable fraction, which is the weight fraction of all inhaled particles deposited in the head or tracheobronchial regions.

Equations for calculating RF and NRF are presented in Volume 7 of this methods series (Versar 1985b). These equations require supporting data on particle size distribution. Since such data is rarely available, NRF and RF can be estimated by using the ICRP model presented as Figure 7-1, provided that data is available on particle mass median diameter. Results using this model are not as reliable as those using actual size distribution data, however.

Table 7-1. Summary of Human Inhalation Rates for Men, Women and Children by Activity Group (m^3/hour)[a]

	Resting	Light	Heavy	Maximal (exercise)
Men	0.42	1.5	2.6	6.7
Women	0.41	10.5	1.5	5.4

[a] Derived from average lung ventilation values at different levels of activity as a function of age and sex, presented in reference man (ICRP 1974).



Source: Meyer (1983).

Figure 7-1. ICRP Model of Regional Respiratory Tract Deposition as a Function of Particle Size

7.3 Dermal Exposure

Despite the relative simplicity of most dermal exposure calculations, dermal exposure presents some conceptual difficulties that are not associated with inhalation or ingestion exposure. Exposure is defined as the amount of substance contacting the receptor and available for absorption. Absorption occurs when the substance crosses a physical barrier to penetrate the tissues of the receptor. "Contact" merely implies that the substance has touched the body of the receptor. "Availability" indicates that the substance has reached (but not crossed) the absorptive barrier. In the case of inhalation and ingestion, the substance is taken into a body cavity (mouth, lungs) prior to absorption. Therefore, the substance is made available by swallowing or inhaling, and the quantity to which the receptor is exposed is equivalent to the quantity inhaled or swallowed. In the case of dermal exposure, the substance contacts only the outer surface (skin) of the receptor and is not taken into the body until is has penetrated the skin (i.e., after it has been absorbed). This makes it difficult to define "exposure" when the receptor is in contact with large ambient volumes of liquids or gases, or with a small portion of a large solid surface.

The sections that follow delineate methods for use in estimating workplace dermal exposure via three pathways: (1) exposure to a film of liquid deposited on the skin; (2) exposure to dusts and powders deposited on the skin; and (3) exposure of skin to chemical substances contained in or adhering to solid matrices. A method for assessing exposure during immersion of skin in liquids is not presented. The major problem with attempting to assess exposure during immersion of skin in liquids is that the portion of the entire mass of the chemical substance in the solution that is in contact with the receptor is not known. Obviously, the skin of the receptor is not in contact with the entire volume of the solution. Attempts to assess exposure for this pathway without taking into consideration parameters needed to estimate absorbed dose may not be very meaningful.*

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*Refer to Versar (1985b) for a discussion of contaminant dose estimation using chemical-specific absorption rate data. It is recognized, however, that data quantifying chemical flux across human skin from concentrated, dilute, or mixed solutions is sparse at best. Also, the method presented in Versar (1985b) does not take into account time-dependent absorption, and its application is thus further constrained.

7.3.1 Exposure to a Film of Liquid Deposited on the Skin

Most significant, quantifiable dermal exposure involves liquid films in the skin. This may result from spills, brief immersion (e.g., of a hand) followed by rapid withdrawal so that a film remains, or by touching a wet surface. It may also occur by exposure to airborne droplets, provided that the spray is sufficient to form a continuous film when it hits the skin.

Exposure is usually expressed as mass per year. For each exposure, the assessor determines the amount of substance deposited on the skin on the basis of (1) estimated volume of liquid deposited and (2) estimated concentration of subject chemical in the deposited liquid. This, multiplied by the number of annual exposures, yields total mass per year. Since exposure is by direct physical contact, no fate or transport related parameters are involved.

The product obtained by multiplying (1) the area of skin likely to be exposed during ordinary contact by (2) the film thickness is an estimate of the volume of liquid on the skin. This parameter is independent of the quantity of liquid initially contacted, since most liquid spilled on the skin will drip off immediately and not be available for absorption. The film thickness of a liquid can be determined using the following equation:

$$\text{Film thickness (cm)} = \frac{\text{amount of liquid retained on skin (mg/cm}^2\text{)}}{\text{density of liquid (g/cm}^3\text{)} \times 1000 \text{ (mg/g)}} \qquad (7\text{-}4)$$

Values of amount of liquid retained on skin for six selected liquids are presented in a study to assess exposure resulting from retention of chemical liquids on hands (Versar 1984c). In this study, the retention of selected liquids on the hands of human volunteers was measured under five conditions of exposure. The five conditions included: (1) initial uptake; (2) secondary uptake; (3) uptake from handling a rag; (4) uptake from spill clean-up; and (5) uptake from immersion of a hand in a liquid.

Initial uptake, secondary uptake, and uptake from handling a rag all involve contact by an individual with a rag saturated with a liquid for which adherence to the skin was being determined. The test for initial uptake, a rag saturated with liquid was rubbed over the front and back of both hands for the first time during an exposure event. To test for secondary uptake, as much liquid that adhered to the skin during initial uptake was removed as was possible using a clean rag. A rag saturated with the liquid was then rubbed over the front and back of both hands for the second time during an exposure event. To test for uptake from handling a rag, a rag saturated with a liquid was rubbed over the palms of both hands for the first time during an exposure event in a manner simulating handling of a wet rag. In the test for uptake from immersion, an individual immersed one hand in a container of luquid, removed the hand, then allowed the liquid to drip from the hand back into the container for 30 seconds (one minute for cooling oil). In the test for uptake from spill cleanup, an individual used a clean rag to wipe up 50 milliliters (ml) of liquid poured onto a plastic laminate counter top.

For each exposure condition, the quantity of liquid retained on the hands was determined (1) immediately following the exposure condition, (2) after a partial wipe, and (3) after a full wipe (except in the cases of uptake by immersion and uptake from spill cleanup). A partial wipe refers to a light, quick wipe with a clean rag. A full wipe refers to a thorough, complete wipe with a clean rag.

The six liquids used in this study were selected to represent a broad range of kinematic viscosities. The liquids used were (1) mineral oil, (2) cooking oil; (3) water-soluble oil (bath oil), (4) oil/water emulsion (50:50, water:water-soluble oil), (5) water, and (6) water/ethanol (50:50). Table 7-2 presents values of film thickness for these six liquids under each of the five exposure conditions immediately following exposure, after a partial wipe, and after a full wipe. Many types of liquids were not included in this study. To assess dermal exposure to films deposited on the skin for liquids that are not listed in this table, it is suggested that one use as a default value data for film thickness for the liquid listed in the table that most closely resembles the liquid being assessed. Two physical properties that may be used to compare liquids are kinematic viscosity and density. The experimentally determined values for density and kinematic viscosity for the six liquids used in the study to assess exposure from retention of liquids on hands are presented in Table 7-3. Note that the error from using default values as values of film thickness for liquids not listed in Table 7-2 may be considerable. In the study to assess exposure from retention of liquids on hands, the relationship between kinematic viscosity and mass of liquid retained per cm^2 of skin was examined. Although liquid retention was found to increase with kinematic viscosity, the data did not support a functional relationship between these two parameters. Additional liquids need to be examined to determine whether such functional relationship exists between these two parameters.

Table 7-2. Film Thickness and Density of Selected Liquids under Various Experimental Conditions (10^{-3} cm)

Film thickness (10^{-3} cm)	Mineral oil	Bath oil	50% Bath oil in water	Water	50% Ethanol in water
Initial uptake[a]	1.62	1.99	2.03	2.34	3.25
Wet rag[b]	1.64	2.04	1.88	2.10	4.17
Immersion[c]	15.86	11.85	8.49	3.27	3.60
Density (g/cm^3)[d]	0.872	0.866	0.936	0.999	0.930

[a] Determined as follows: the subject wipes his (dry) hand with a rag saturated with the subject chemical; clean rags are then used to recover the deposited liquid. The clean rags are weighed before and after use, and the difference is taken to be the weight of the film initially deposited.

$$\text{Film thickness (cm)} = \frac{\text{liquid concentration (mg/cm}^2\text{)}}{\text{density (g/cm}^3\text{)} \times 1000 \text{ (mg/g)}}$$

[b] Determined as above except that initial contact is by handling the saturated rag as a wet rag might ordinarily be handled.

[c] Subject immerses hand up to wrist in a container of subject liquid, withdraws hand, and allows it to drip for 30 seconds. Hand is then wiped with clean rags, and calculations are performed as above.

[d] Determined experimentally.

Source: Versar 1983b.

Table 7-2. (continued)

	Mineral oil	Cooking oil	Bath oil	Oil/ water	Water	Water/ ethanol
Uptake from immersion						
Estimated initial film thickness of liquid on hand	5.88	11.28	12.06	9.81	4.99	6.55
Estimated film thickness of liquid remaining after partial wipe	1.49	1.59	1.51	2.42	2.14	2.93
Uptake from Spill Cleanup						
Estimated initial film thickness of liquid on hand	1.23	0.73	0.89	1.19		
Estimated film thickness of liquid remaining after partial wipe	0.55	0.51	0.48	1.36		

Table 7-3. Experimentally Determined Values for Density and Kinematic Viscosity for Six Selected Liquids

Liquid	Density (g/cm^3)	Kinematic viscosity (cSt)
Mineral oil	0.8720	183.0
Cooking oil	0.9161	65.4
Bath oil	0.8660	67.2
Bath oil/water	0.9357	4.19
Water	0.9989	1.02
Water/ethanol	0.9297	2.55

Source: Versar 1984c.

The basic equation for exposure via a liquid film is as follows:

$$DEX = WF \times DSY \times AV \times T \times FQ \times P \qquad (7\text{-}5)$$

where

DEX = annual dermal exposure (mg/yr)
WF = weight fraction of chemical in mixture (unitless)
DSY = density of formulation (mg/cm^3)
AV = available skin area (cm^2)
T = film thickness (cm)
FQ = frequency (exposure events/yr)
P = protection factor

The density factor (DSY) is required to convert the units. Note that "ml" is taken to be equivalent to cubic centimeters. The density is presumed to be that of the subject chemical, unless it is an ingredient of a mixture. In that case, the density of the mixture can be presumed to be the density of the principal solvent. Similarly, the weight fraction parameter (WF) is necessary only when the substance is contacted as an ingredient of a mixture.

Available skin area (AV) depends on the operation being performed. Routine spills will probably be to one hand. Maintenance activities that involve touching wet surfaces may involve the palm only. More extensive spills are not predictable occurrences. Surface areas of body parts are given in Table 7-4.

The protection factor (P) is explained in Section 7.1. It should be noted that Equation 7-5 is limited to cases where the film is continuous and of a constant, predictable thickness. The equations may overestimate exposure via a liquid spray where the droplets do not flow together to form a continuous film, and it may underestimate exposure to such substances as paints and adhesives that are formulated specifically to adhere to surfaces. The latter may form layer upon layer on the skin so that final thickness is not predictable.

7.3.2 Exposure to Dusts and Powders

Exposure to dusts and powders is conceptually similar to exposure to liquid films, since it involves the deposition of a limited quantifiable amount of product on the skin. Calculation of exposure in both cases uses essentially the same parameters, with "dust adherence" roughly analogous to "film thickness." However, dust adherence is expressed directly as mass per unit skin surface and does not require a density factor to convert volume to mass.

Table 7-4. Surface Area of Body Regions[a]

Body region	Percent of total surface area		Generic surface area (cm^2)		
	Male	Female	Male	Female	Average adult[b]
Total adults[c]	100	100	19,400	16,900	18,150
Head and neck	7.8	7.1	1,180	1,100	1,140
Face[d]	2.6	2.4	390	370	380
Neck[d]	2.6	2.4	390	370	380
Scalp[d]	2.6	2.4	390	370	380
Upper extremities[e]	18.8	17.9	3,190	2,760	2,975
Arms (both, excluding hands)	14.1	14.0	2,280	2,100	2,190
Upper arms[f]	7.4	7.4	1,430	1,250	1,340
Forearms[f]	5.9	5.9	1,140	1,000	1,070
Hands	5.2	5.1	840	750	795
Outstretched palm and fingers[g]	2.6	2.6	420	375	400
Lower extremities[h]	37.5	40.3	6,360	6,250	6,310
Legs	31.2	32.4	5,050	4,880	4,970
Thighs	18.4	19.5	1,980	2,950	2,470
Lower legs	12.8	12.8	2,070	1,940	2,005
Feet	7.0	6.5	1,120	975	1,050
Trunk	35.9	34.8	5,690	5,420	5,555
Total, 3-6 year-old child[c]	100	100	7,280	7,110	7,200
Total, 6-9 year-old child[c]	100	100	9,310	9,190	9,250
Total, 9-12 year-old child[c]	100	100	11,600	11,600	11,600

[a] Unless otherwise noted, values for surface area presented in this table are mean values reported in Anderson et al. (1984).

[b] Values presented in this table for average surface area are the average of values reported or derived for males and females.

[c] The values for surface area of the total body presented in this table for adults and children are based on values of surface area, reported for the 50th percentile group in Anderson et al. (1984).

[d] Values presented for surface area of this body region are based on the assumption that this body region comprises one-third of the surface area of the head and neck.

[e] Includes arms and hands.

[f] Anderson et al. (1984) do not report values for females for these body regions; values presented were obtained by applying the percentage of total body surface area reported for males for these body regions to the total body surface area value for females presented in this table.

[g] A value of one-half the surface area of the hands is assumed.

[h] Includes legs and feet.

Unfortunately, data on dust adherence to skin is limited. Data generated by the Toxic Substance Control Commission of the State of Michigan indicate the following (Harger 1979):

- Vacuum cleaner dust sieved through an 80-mesh screen adheres to human hands at 3.44 mg/cm^2.
- Dust of the clay mineral kaolin adheres to hands at 2.77 mg/cm^2.
- Commercial potting soil adheres to hands at 1.45 mg/cm^2.

The conditions of the experiment were not reported. Since the research was performed to support predictions of occupational exposure to the chemical MBOCA, and since occupational contact is likely to yield maximum saturation of the skin, it will be assumed that the experimental conditions were designed to encourage maximum adherence (Versar 1982). However, it is not known which physical or chemical properties of a powdered substance determine the extent of its adherence to skin; therefore, it is not possible to predict the extent to which the three substances tested may represent substances commonly encountered in the occupational environment.

Until more data become available, the value for vacuum cleaner dust may be used as an upper limit. Substances that are lipophilic or surfactant, or that tend to clump in the presence of skin moisture, can adhere to a greater extent.

The following equation can be used to calculate dermal exposure to dusts.

$$DEX = WF \times AV \times FQ \times DA \times K \tag{7-6}$$

where

DEX = exposure (mg/yr)
WF = weight fraction of chemical in material contacted (unitless)
AV = available skin area (cm^2)
FQ = frequency (events/year)
DA = maximum dust adherence (see above), (mg/cm^2)
K = arbitrary factor, unitless, ranging from 0 to 1 to express fraction of maximum adherence expected in a particular case.

7.4 Ingestion Exposure

Two types of ingestion exposure are likely to occur in the workplace. The first is ingestion as a subset of inhalation exposure, i.e., the gastrointestinal deposition of inhaled airborne particulates too large to be respired. This is discussed in Section 7.2 (see Equation 7-3). The other type of exposure follows from initial dermal exposure. In this situation, a chemical that has been deposited on the skin is transferred to the mouth area and accidentally ingested. The magnitude of such exposure would depend on (1) the magnitude of the initial dermal exposure; (2) the extent to which this is transferred to the mouth area; and (3) the extent to which the chemical is then taken into the mouth (e.g., by licking the lips). The second and third requirements are virtually impossible to quantify. (It is assumed that obviously contaminated hands would not be directly placed into the mouth, although employees working with highly toxic substances have been known to handle food or cigarettes without washing their hands.)

Dermal exposure may lead to ingestion exposure more directly in very dusty environments where dust is deposited directly on the face. As a reasonable worst-case, it can be assumed that the entire quantity of dust that covers the lips is ingested. This can be estimated using the dermal exposure Equation 7-6. The surface area of the lips has been estimated to be 7 cm^2 (Versar 1984d). These types of ingestion exposure are not possible when the employee wears a respirator.

It should be noted, however, that differentiation between inhalation/ingestion or dermal/ingestion exposure may not be necessary in all cases. Such exposure is only important in those situations where the health effects or absorption of a chemical depend on the exposure route.

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APPENDIX A

PROCESSES AND EXPOSURE POTENTIAL

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A-2. PLASTICS MANUFACTURE AND PROCESSING
A-3. LUBRICANTS AND HYDRAULIC FLUIDS PROCESSING
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APPENDIX A-1

Synthetic Organic Chemicals Manufacture

INTRODUCTION

This appendix is organized into 23 categories that correspond to the 23 major large-volume synthetic organic chemicals manufacturing industry (SOCMI) "unit process" components that carry out the fundamental synthesis reactions, e.g., halogenation, alkylation.

It provides a description of each unit process with available release data. With regard to its utility in occupational exposure assessments, this material is broadly useful in supporting development of a materials mass balance for a given chemical process, and is specifically useful for identifying waste streams to which workers in on-site industrial waste treatment facilities may be exposed.

1.0 ALKYLATION PROCESSES

Alkylation is the introduction of an alkyl radical to an organic compound by substitution or addition. The most common alkylation products are ethylbenzene and cumene. Other products and their 1980 production are found in Table 1. Figure 1 is a generalized process flow diagram for an alkylation process.

1.1 Description of Discharges

Releases from the alkylation processes occur as fugitive and particulate gaseous emissions, liquid wastes, and solid residues. The major sources of air contamination are: 1) feedstock emissions and 2) volatile by-products.

Wastewaters may be released from within the process if process operating conditions require. They may also occur from washdown of process vessels, or they may be formed during chemical reactions. These waste streams contain caustic and caustic-catalyst fines, and feedstock lead (from the lead alkyls process) will result from distillation column bottoms and product settling basins.

fugitive gaseous emissions - may occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains, and cooling towers.

reactor - gaseous releases may occur at the reactor vent.

caustic scrubber - liquid waste may occur from caustic wash.

feedstock stripper
- gaseous releases may occur from the column vent.
- sludge may be released as wastewater from the column bottoms.

purification columns
- gaseous releases may occur from the column vent.
- liquid wastes may be released in the column bottoms.

Specific releases from alkylation processes are addressed in Versar (1982).

TABLE 1. ALKYLATION PRODUCTS AND THEIR MANUFACTURE IN 1980

Product	Amount* (kkg)	Feedstock	Other Required Processes
Acetic acid	NA	n-Butenes	Oxidation
Alkylbenzenes	94,347	Benzene Propylene tetramer	None
Alkylbenzenes (linear)	87,090	Benzene Linear olefins	None
Alkylbenzenes (linear)	157,850	Benzene Linear paraffins	Dehydrogenation
Benzene, xylenes	NA	Toluene	None
p-tert-Butylphenol	NA	Phenol Isobutene	None
Cumene	1,932,304	Benzene Propylene	None
Ethylbenzene	3,516,611	Benzene Ethylene	None
N-Isopropyl-N'-phenol-p--phenylenediamine	NA	p-Chloronitrobenzene Aniline Acetone	Dehydrohalogenation Hydrogenation
Lead alkyls	>259,455	Ethyl chloride (Alkyl chlorides)	None
p-nonyl phenol	147,690	Phenol Propylene trimer	None
Phenol, acetone	1,436,255	Benzene Propylene	Acid cleavage Hydrolysis Oxidation
Pyromellitic deanhydride	NA	1,2,4-trimethylbenzene (pseudocumene)	Oxidation
Styrene	3,263,688	Benzene Ethylene	Dehydrogenation
2,4-xylenol	NA	p-cresol Methylchloride	None

*SRI lists amounts in plant capacities. For this table, the capacities were multiplied by 0.8.

Source: Herrick et al. 1979a; SRI 1981.

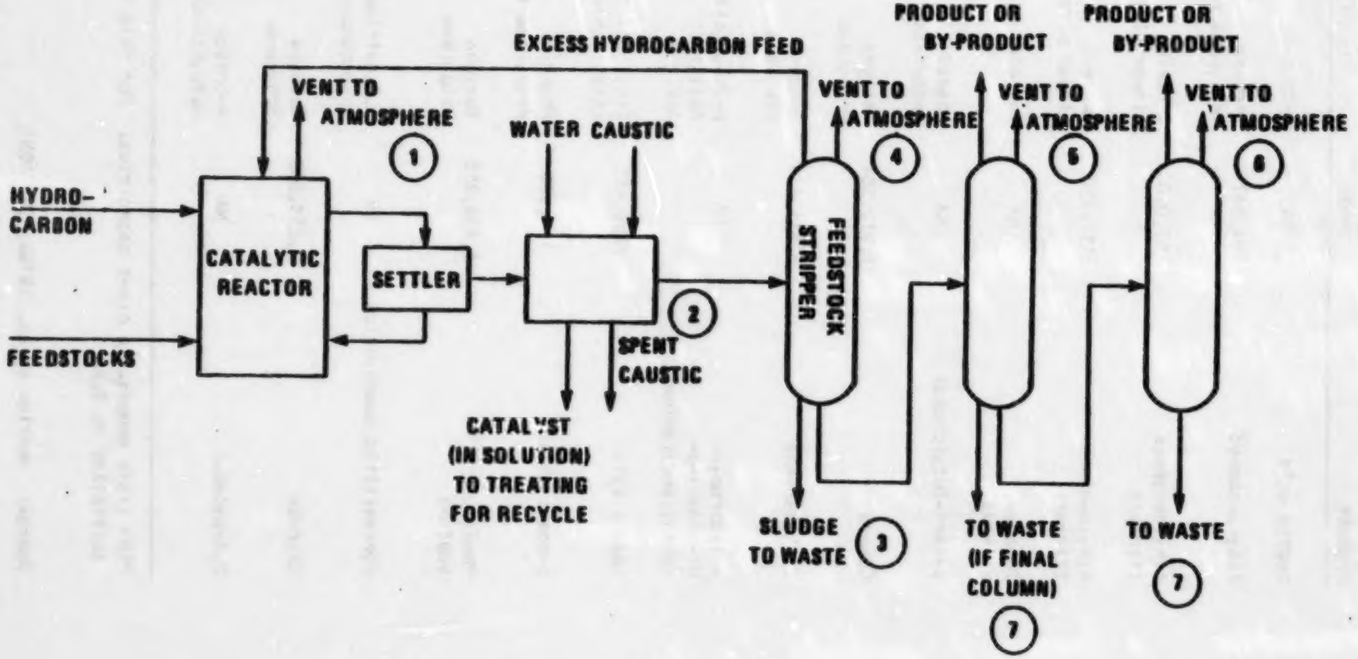

HYDRO-
CARBON
FEEDSTOCKS
CATALYTIC REACTOR
VENT TO ATMOSPHERE
①
SETTLER
WATER
CAUSTIC
②
SPENT CAUSTIC
CATALYST (IN SOLUTION) TO TREATING FOR RECYCLE
EXCESS HYDROCARBON FEED
FEEDSTOCK STRIPPER
VENT TO ATMOSPHERE
④
SLUDGE TO WASTE
③
PRODUCT OR BY-PRODUCT
VENT TO ATMOSPHERE
⑤
TO WASTE (IF FINAL COLUMN)
⑦
PRODUCT OR BY-PRODUCT
VENT TO ATMOSPHERE
⑥
TO WASTE
⑦

Figure 1. Generalized process flow diagram for manufacture of alkylated organic compounds. Source: White 1980a; Kirk-Othmer 1978.

2.0 AMINATION BY AMMONOLYSIS

The formation of amine by reacting ammonia with organic compounds is the process of amination by ammonolysis. Many products of amination, such as methylamines, ethylamines, aniline and ethyline diamines,are listed in Table 2 with their 1980 production amounts. A generalized process flow diagram of an amination by ammonolysis process is presented in Figure 2.

2.1 Description of Discharges

Basically, all amination processes produce the same type of emissions. Feedstock excess ammonia that does not get recycled is always a discharge to be considered. Organic feedstock that does not completely convert, approximately 1%, usually goes to waste and/or recycle. With a final yield of 95%, final product fugitive emissions and waste organic product from side reactions make up about 5% of the aminated products (Cocuzza et al. 1979, Habermann 1979, Klabunde 1979). Some of this may be recycled, but like the feedstocks, the exact amount that is emitted and does not get recycled is unknown. Also, solid catalyst fines are present in the wastewater of all amination processes except for ethanolamine and for ethylene diamine produced from ethylene dichloride, but the amount is unknown.

Specific releases from amination by ammonolysis processes are presented in Versar (1982).

3.0 AMMOXIDATION

Ammoxidation is a process in which nitriles are formed by the reaction of ammonia in the presence of air or oxygen with olefins, organic acids, or the alkyl group of alkylated aromatics. The major products made by ammoxidation processes are listed in Table 3 with their 1980 production amounts. Figure 3 presents a generalized process flow diagram for ammoxidation processes. More detailed explanations are provided in Versar (1982).

TABLE 2. AMINATION PRODUCTS AND THEIR MANUFACTURE IN 1980

Product	Amount (kkg)	Feedstock	Other Required Processes
Aniline	NA	Phenol	
Benzene sulfonamide	NA	Benzene sulfonyl chloride	
p-Chlorobenzene sulfonamide	NA	p-Chlorobenzene Sulfonyl chloride	
Dimethyl-formamide	NA	Dimethylamine Methyl formate	
Ethanolamines	194,138	Ethylene oxide	
Ethanolamines	NA	Ethanol	
Ethylenediamine	72,575*	Ethylene dichloride	
Ethylenediamine	NA	Monoethanolamine	
Hexamethylenediamine	145,150	Adipic acid	
Hexamethylenetatramine	54,068	Formaldehyde	Condensation
Methylamines	134,989	Methanol	
Urea	2,580,759 (total)	Carbon dioxide	Dehydration

Source: Herrick et al. 1979a; SRI 1981.

*Feedstock not specified.

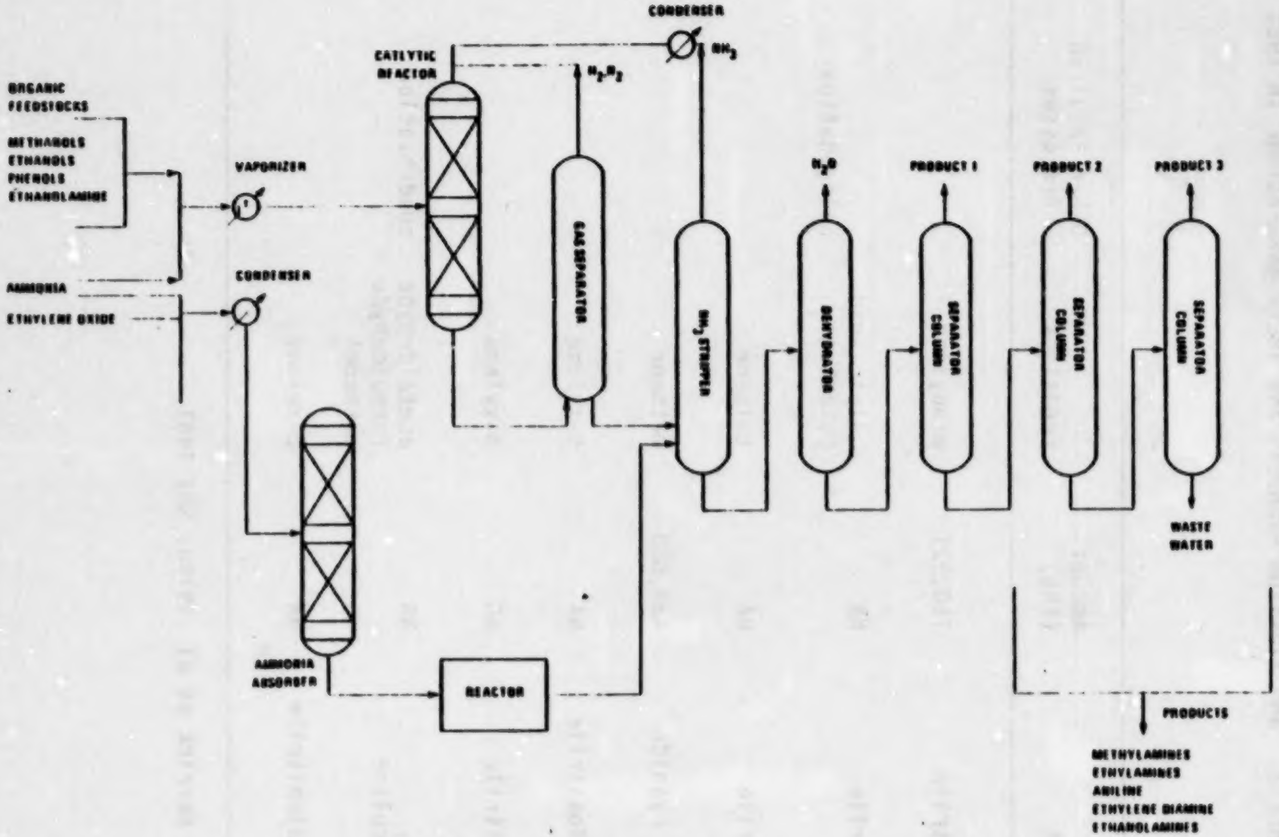
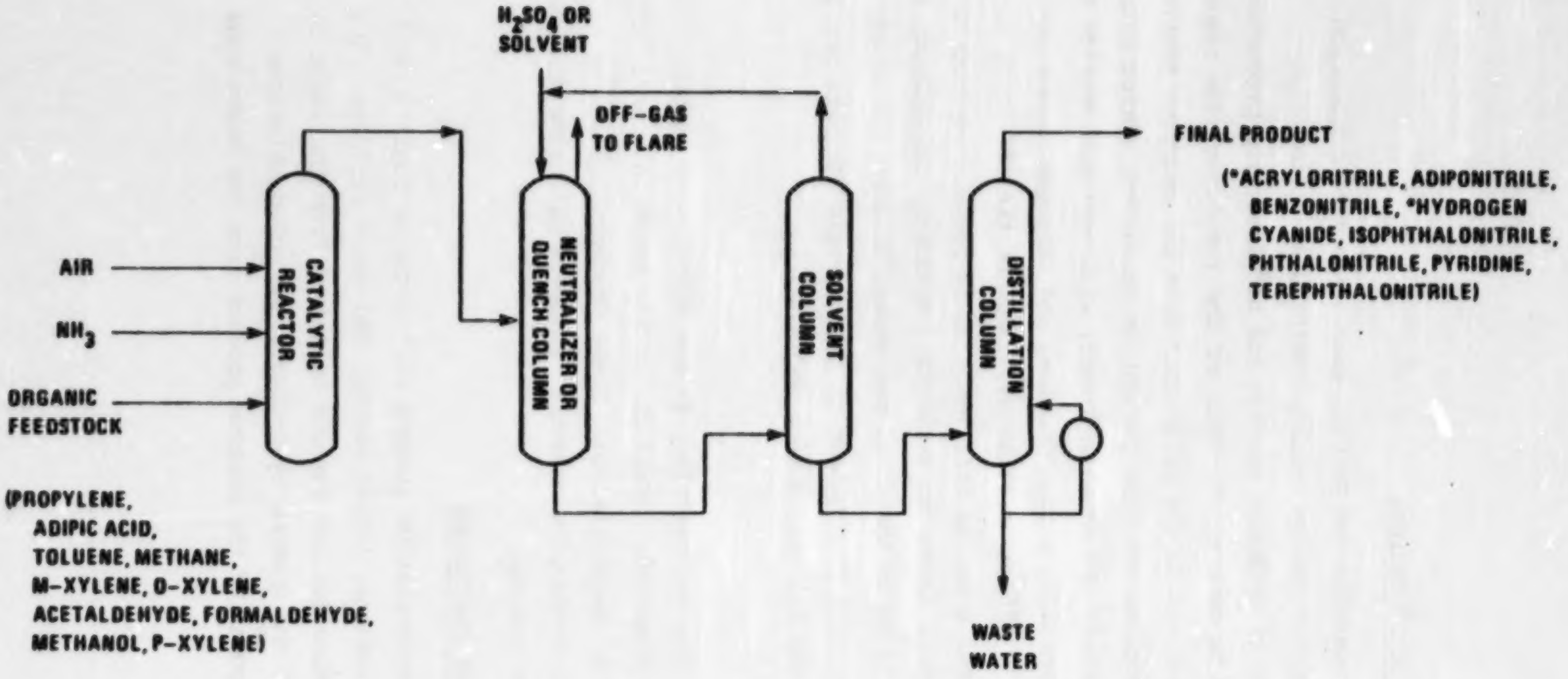

ORGANIC FEEDSTOCKS
METHANOLS
ETHANOLS
PHENOLS
ETHANOLAMINE
AMMONIA
ETHYLENE OXIDE
VAPORIZER
CONDENSER
CATALYTIC REACTOR
H_2,N_2
GAS SEPARATOR
CONDENSER
NH_3
NH_3 STRIPPER
AMMONIA ABSORBER
REACTOR
H_2O
DEHYDRATOR
PRODUCT 1
SEPARATOR COLUMN
PRODUCT 2
SEPARATOR COLUMN
PRODUCT 3
SEPARATOR COLUMN
WASTE WATER
PRODUCTS
METHYLAMINES
ETHYLAMINES
ANILINE
ETHYLENE DIAMINE
ETHANOLAMINES

Figure 2. Generalized flow diagram of amination plant.
Source: Herrick et al. 1979b.

TABLE 3. AMMOXIDATION PRODUCTS AND THEIR MANUFACTURE IN 1980.

Product	Amount (kkg)	Feedstock	Other Required Processes
Acrylonitrile	760,221	propylene	
Adiponitrile	NA	adipic acid butadiene	halogenation
Benzonitrile	NA	toluene	
Hydrogen cyanide	439,803	methane	
Isophthalonitrile	NA	n-xylene	
Phthalonitrile	NA	o-xylene	
Pyridine, beta-picoline	NA	acetaldehyde formaldehyde methanol	condensation
Terephthalonitrile	NA	p-xylene	

Source: Herrick et al. 1979a; SRI 1981.


H_2SO_4 OR SOLVENT
OFF-GAS TO FLARE
AIR
NH_3
ORGANIC FEEDSTOCK
CATALYTIC REACTOR
NEUTRALIZER OR QUENCH COLUMN
SOLVENT COLUMN
DISTILLATION COLUMN
FINAL PRODUCT
(*ACRYLORITRILE, ADIPONITRILE, BENZONITRILE, *HYDROGEN CYANIDE, ISOPHTHALONITRILE, PHTHALONITRILE, PYRIDINE, TEREPHTHALONITRILE)
(PROPYLENE, ADIPIC ACID, TOLUENE, METHANE, M-XYLENE, O-XYLENE, ACETALDEHYDE, FORMALDEHYDE, METHANOL, P-XYLENE)
WASTE WATER

*ACRYLONITRILE AND HYDROGEN CYANIDE ARE NEUTRALIZED WITH H_2SO_4 FOLLOWING REACTION; OTHER PRODUCTS ARE QUENCHED WITH A SOLVENT

Figure 3. General ammoxidation process.

3.1 Description of Discharges

In addition to feedstocks and product emissions, the hydrocarbon solvent added to the quench column usually contributes to reaction emissions. In the case of hydrogen cyanide and acrylonitrile productions, sulfuric acid is added to neutralize; this and the resulting side reaction forming ammonium sulfate add to the pollutants from the reaction section. Products from side reactions are also present in emissions. Other nitriles besides the desired product are usually formed, with hydrogen cyanide the most common. Carbon monoxide, carbon dioxide, and nitrogen oxides are also produced and released as off-gases (lights). Most of the off-gases go to an incinerator of greater than 99% efficiency or to recycle (Hydrocarbon Processing 1973); however, there can be leaks. Antimony, molybdenum, or iron particles may be found in the final wastewater because the catalyst is usually an oxide of one or a combination of these metals (Barnett and Dewing, Doihyj et al., Hosler and Baillie, Norton and Bushick).

4.0 CARBONYLATION

Carbonylation, or the Oxo reaction, is the addition of carbon monoxide to an organic compound. Small carbonylic acids, alcohols, and aldehydes are prepared by carbonylation. These products are listed in Table 4 with their 1981 production amounts. Figure 4 is a flow diagram for a typical carbonylation process.

4.1 Description of Discharges

Releases from a carbonylation process will occur as fugitive and particulate gaseous emissions, liquid wastes, and solid residues. The major sources of contamination are gaseous emissions from the vents on the reactors which pull off the gaseous by-products and solid emissions resulting from the disposal of the bottoms product from the heavy ends distillation column.

Table 4. Carbonylation Products and Their Manufacture in 1980

Product[1]	Amount kkg	Feedstock[1]	Other Required Processes[1]
Acetic acid	565,526[2]	Methanol Carbon Monoxide	None
Alcohols (C_7-C_{13})	NA[3]	Olefins Carbon Monoxide	None
n-Butanol/ n-Butyraldehyde	413,681[4] 488,070[4]	Propylene Carbon Monoxide	Hydrogenation
Ethyl acrylate	NA[3]	Acetylene Ethanol Carbon Monoxide	None
2-Ethyl hexanol/ n-Butyl alcohol	125,193[4] same as n-Butanol	Propylene Carbon Monoxide	Hydrogenation
Isobutyraldehyde/ Isobutyl alcohol	118,298[4] 98,340[4]	Propylene Carbon Monoxide	Hydrogenation
Formic acid Sodium formate	27,216[4]	Carbon Monoxide Sodium Hydroxide	Hydrolysis
Formic acid		Carbon Monoxide (Methanol Recycled)	Condensation Hydrolysis

[1] Source: Herrick et al. 1979.

[2] Source: SRI 1981.
Assumes 80% of capacity is produced.
Kirk-Othmer (1980) states that 34 to 37% of all acetic acid is manufactured by methanol carbonylation. This value is 35.5% of the total.

[3] Source: SRI 1981.
Does not give amounts produced, but lists producers.

[4] Source: SRI 1981.
Assumes that 80% of capacity is produced and also assumes that the amount produced was by carbonylation. Capacities may include corresponding iso- or n- compounds; for example, the amount of n-butyraldehyde produced may include iso-butyaldehyde.

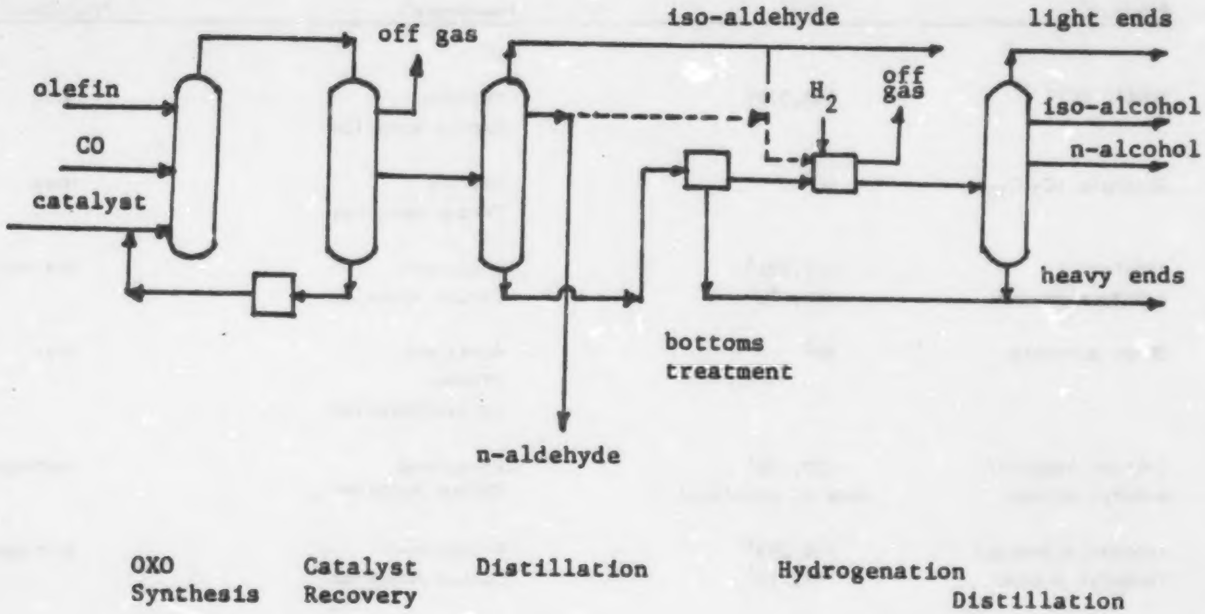

off gas
iso-aldehyde
light ends
olefin
CO
catalyst
H_2
off gas
iso-alcohol
n-alcohol
heavy ends
bottoms treatment
n-aldehyde
OXO Synthesis
Catalyst Recovery
Distillation
Hydrogenation
Distillation

Figure 4. A typical carbonylation process.

Source: Adopted from Hydrocarbon Processing, 1973.

fugitive gaseous emissions	may occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains, and cooling towers.
compression	fugitive emissions will occur, especially at compressor seals.
	liquid wastes will result when flushing the compressors and when the oil used to grease the compressors leaks out.
carbonylation reactor	pollutants will be released from the off-gas vent on the reactor.
cooling and condensing	condensers, partial condensers, and heat exchangers cause contaminated liquid waste streams and vent off-gases.
purification	gas scrubbers, degassers, and water washes create large contaminated liquid waste streams and large gaseous waste streams.
product separation	distillation columns (both conventional and extractive distillation) cause fugitive and intermittent air emissions, solid bottoms products to be disposed, and contaminated liquid wastes containing products and extractive solvents.
steam generation and cooling tower operation	contaminants are released during operation and at blowdown.

All carbonylation reactions release volatile organic compounds (VOCs). VOCs include organic chemicals which, when emitted to the atmosphere, participate in photochemical reactions producing ozone. VOCs are emitted not only to the air, but also to the land and water.

Quantification of releases is presented in Versar (1982).

5.0 CONDENSATION

Condensation is the process where two or more organic chemicals combine to form a main product, usually with the separation of water or some other low-molecular-weight compound. Very diverse groups of organic chemicals are made from condensation reactions. Table 5 lists the 55 organic chemicals manufactured by condensation and figures for their production in 1980. Figure 5 shows a generalized flow diagram for a condensation process. Specific processes with their releases are discussed in Versar (1982).

5.1 Description of Discharges

Releases from a condensation process will occur as fugitive and particulate gaseous emissions, liquid wastes, and solid residues. The major sources of gaseous emissions are from the reactor by-product vents, the column vents on distillation columns, and releases during storage and handling. Since most condensation reactions yield water as a product of the reaction, a contaminated water stream will be discharged to wastewater treatment. Other liquid emissions will occur from disposal of spent scrubbing liquids and other solvents. Solid residues will result if a by-product of the reaction is a low molecular weight solid such as salt (NaCl), which is separated from the other products but contaminated to the same degree as the water of reaction. This solid product may be used elsewhere or disposed of. Another source of solid residues is the bottoms product of the heavy ends distillation column.

Volatile organic compounds (VOC) will be emitted since the condensation products and reactants are organic compounds. Volatile organic compounds (VOCs) have been defined by USEPA as organic compounds which, when emitted to the atmosphere, undergo photochemical reactions producing ozone. Most every organic chemical is a volatile organic compound (VOC). Also included as condensation products are pesticides. The emissions during their manufacture should be carefully monitored and controlled when possible.

TABLE 5. CONDENSATION PRODUCTS AND THEIR MANUFACTURE IN 1980

Product	Amount[1,2] (kkg)	Feedstock	Other Required Processes
Acetic anhydride	726,000[1]	Acetic acid	Pyrolysis
Arsanilic acid (p-aminobenzenearsonic acid)	NA[3]	Aniline Arsenic acid	None
Benzene sulfonyl chloride	NA[3]	Benzene Chlorosulfonic acid	None
Biphenyl (diphenyl)	26,400[2]	Benzene	Dehydrogenation
Bisphenol A	330,200[1]	Acetone Phenol	None
Choline chloride	NA[3]	Ethylene oxide Trimethylamine	Amination by ammonolysis Hydrohalogenation
Crotonaldehyde n-Butyl alcohol n-Butyraldehyde	NA[3]	Acetaldehyde	Hydrogenation
Dichlorodiphenyltrichloroethane [1,1,1-trichloro-2,2-bis-(p-chlorophenyl) ethane](DDT)	26,800[4]	Acetaldehyde Monochlorobenzene	Halogenation
2,4-Dichlorophenoxyacetic-acid (2,4-D)	5,800[2]	Monochloroacetic acid Phenol	Halogenation
2-(2,4-Dichlorophenoxy) propionic acid (2,4-DP)	NA[3]	α-Chloropropionic acid 2,4-Dichlorophenol	Dehydrohalogenation
4,4'-Dichlorophenylsulfone	NA	Monochlorobenzene Sulfur trioxide	None
Diphenylamine	NA[3]	Aniline	None
Diphenylguanidine	NA[3]	Aniline	None
N,N'-Diphenylhydrazine (hydrazobenzene)	NA[3]	Cyanic acid Nitrobenzene	Hydrogenation
Diphenylmethane-4-4'-diisocyanate [(methylene-bis 4-phenylisocyanate)] (MDI)	209,000[1]	Aniline Formaldehyde Phosgene	Phosgenation

Table 5. (Continued)

Product	Amount[1,2] (kkg)	Feedstock	Other Required Processes
Ethyl acetate	94,300[1]	Acetaldehyde	None
Ethyl carbonate	NA[3]	Ethylene oxide Carbon dioxide	None
Ethylene glycol ethers	555,000[5]	Alkyl alcohols Ethylene glycol	None
Ethylene glycol monoethyl ether		Ethylene oxide Ethanol	None
Ethyl ether (diethyl ether)	23,200[1]	Ethanol	None
2-Ethylhexanol	125,200[1]	Acetaldehyde Butyraldehyde	Hydrogenation
Ethyl parathion (parathion)	NA[3]	O,O-Dimethyl phosphoro-Thionochloridate Sodium nitrophenoxide	Halogenation
Formic acid	27,200[1]	Carbon monoxide (methanol recycled)	Carbonylation Hydrolysis
Heptenes	54,400[1]	Butylenes Propylene	None
Hexamethylenetetramine	54,000[1]	Ammonia Formaldehyde	Amination by ammonolysis
Isophorone	NA[3]	Acetone	None
Isoprene (2-methyl-1,3-butadiene)	143,300[1]	Propylene	Cracking
Isoprene		Acetone Acetylene	Dehydration Hydrogenation
Isoprene		Formaldehyde Isobutylene	Cracking
Isoprene		Formaldehyde Hydrogen chloride Isobutylene	Hydrohalogenation Pyrolysis

Table 5. (Continued)

Product	Amount[1,2] (kkg)	Feedstock	Other Required Processes
N-Isopropyl-N'-phenyl-p-phenylenediamine	NA[3]	Acetone Aniline p-Chloronitrobenzene	Alkylation Dehydrohalogenation Hydrogenation
Melamine	54,400[1]	Dicyandiamide	Pyrolysis
Melamine		Urea	Pyrolysis
Mesityl oxide	NA[3]	Acetone	Dehydration
DL-methionine	NA[3]	Acrolein Cyanic acid Methyl mercaptan	Hydrogenation
2-Methyl-2-butanol (tert-amyl alcohol)	NA[3]	Acetone Acetylene	Hydrogenation
2-Methyl-3-butyn-2-ol	NA[3]	Acetone Acetylene	None
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	NA[3]	o-Cresol Monochloroacetic acid	Halogenation
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	NA[3]	α-Chloropropionic acid	Dehydrohalogenation
2-Methyl-5-ethylpyridine (MEP) (5-ethyl-2-picoline)	NA[3]	Acetaldehyde Ammonia	Amination by ammonolysis
Methyl isobutyl ketone	83,800[1]	Acetone Hydrogen	Dehydration Hydrogenation
Methyl parathion (0,0-dimethyl 0-p-nitrophenyl phosphorothioate)	23,200[4]	0,0-Aimethyl phosthionochloridate Sodium p-nitrophenoxide	Halogenation
4-Methyl-1-pentene	NA[3]	Propylene	None
N-phenyl-2-naphthylamine	NA[3]	Aniline 2-naphthol	None

Table 5. (Continued)

Product	Amount[1,2] (kkg)	Feedstock	Other Required Processes
Oxalic acid	NA[3]	Sodium formate	Pyrolysis
Pentaerythritol	64,600[1]	Acetaldehyde Formaldehyde	Cannizzaro reaction
p-Phenylphenol (4-hydroxydiphenyl)	NA[3]	Benzene Cyclohexanone	Dehydrogenation
Polyethylene terephthalate	435,400[1]	Dimethyl terephthalate Ethylene glycol	Polymerization
beta-Propiolactone	NA	Formaldehyde Ketone	None
Propylene carbonate	NA[3]	Carbon dioxide Propylene oxide	None
Pyridine beta-Picoline	21,800[1]	Acetaldehyde Formaldehyde Methanol	Ammoxidation
Tetrahydrofuran, 2,3,4,5-tetracarboxylic dianhydride	57,300[1]	Furan Maleic anhydride	Oxidation
Tetramethylthiuram disulfide (thiram) [bis(dimethylthiocarbamoyl)-disulfide]	NA[3]	Ammonia Carbon disulfide Dimethylamine Hydrogen peroxide	Oxidation
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	6,600[4]	Acetic acid 2,4,5-Trichlorophenol	Halogenation
Zineb (zinc ethylenebisdithiocarbamate)	800[2]	Carbon disulfide Ethylene diamine Zinc sulfate	None

Table 5. (Continued)

Product	Amount[1,2] (kkg)	Feedstock	Other Required Processes
Ziram (zinc dimethyldithiocarbamate)	1,700[2]	Carbon disulfide Dimethylamine Zinc sulfate	None

Source: Herrick et al. 1979a.

[1] Source: SRI 1981. Assume 80% of capacity is produced and also assume that the amount produced was by condensation.

[2] Source: USITC 1979.

[3] Source: SRI 1981. Does not give amounts produced, but lists producers.

[4] Source: USITC 1975.

[5] Source: White 1980b. Most of the 555,000 kkg were produced by a different reaction - the reaction of ylene oxide ethylene oxide and alcohols.

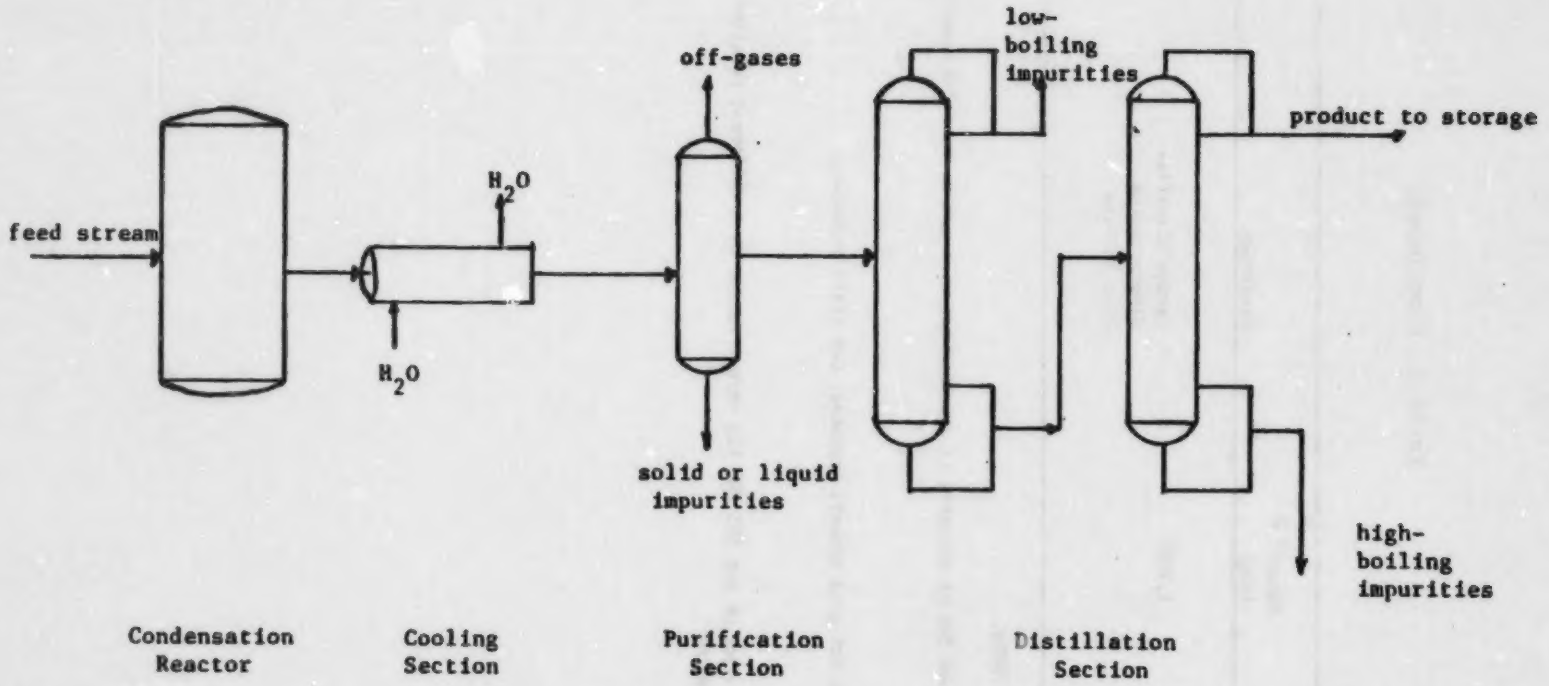

feed stream
H_2O
H_2O
off-gases
solid or liquid impurities
low-boiling impurities
product to storage
high-boiling impurities
Condensation Reactor
Cooling Section
Purification Section
Distillation Section

Figure 5. A generalized flow diagram of a condensation process.

fugitive gaseous emissions - may occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains, and cooling towers.

Preheating the reactants - if steam evaporators or heat exchangers are used, the steam will become contaminated.

Furnaces - the combustion gases will be contaminated with incomplete combustion product and oxides of nitrogen (NO_x).

- hydrocarbon and coke particulate emissions will occur when decoking the furnace.

Reactors - fugitive emissions will occur from reactors when the catalysts or packing are regenerated; this will create an intermittent gaseous or liquid waste stream.

Product cooling - quench waters or solvents will become contaminated because they come in direct contact with the products.

Product purification - if centrifuges are used, absorbers and caustic and water scrubbers will have contaminated liquid waste streams.

steam generation and cooling tower operation - contaminants are released during operation and at blowdown.

6.0 CATALYTIC CRACKING

Catalytic cracking is the thermal decomposition of an organic compound in the presence of a catalyst and in the absence of air. The process is mainly used to create gasoline, C_3-C_4 olefins, and isobutane by selective decomposition of heavy distillates. Chemicals that are produced by catalytic cracking other than gasoline are listed in Table 6. A typical flow diagram for the catalytic cracking process is given in Figure 6.

TABLE 6. CATALYTIC CRACKING PRODUCTS[1] AND THEIR MANUFACTURE IN 1979[2]

Product	Amount (kkg)	Feedstock	Other Processes Required
Isoprene	248,561[3]	propylene	condensation
Isoprene	NA	amylenes	none
Isoprene	NA	isobutylene and formaldehyde	condensation
Perchloroethylene and trichloroethylene	NA	ethylene dichloride	halogenation
Perchloroethylene and trichloroethylene	NA	acetylene	halogenation
Perchloroethylene and trichloroethylene	350,640	any C_2 chlorocarbon	halogenation
Vinyl chloride monomer	108,862[4]	acetylene	halogenation
Vinyl chloride monomer	254,012[4]	ethylene	halogenation
Vinyl chloride monomer	NA	naptha	dehydrohalogenation halogenation oxyhalogenation
Vinyl chloride monomer	1,823,440[4]	ethylene	halogenation oxyhalogenation

Sources:

[1] Herrick et al. 1979a.
[2] USITC 1979.
[3] Total production from all manufacturing processes.
[4] SRI 1981. Assumed 80% of nameplate capacity.
NA - Not available.

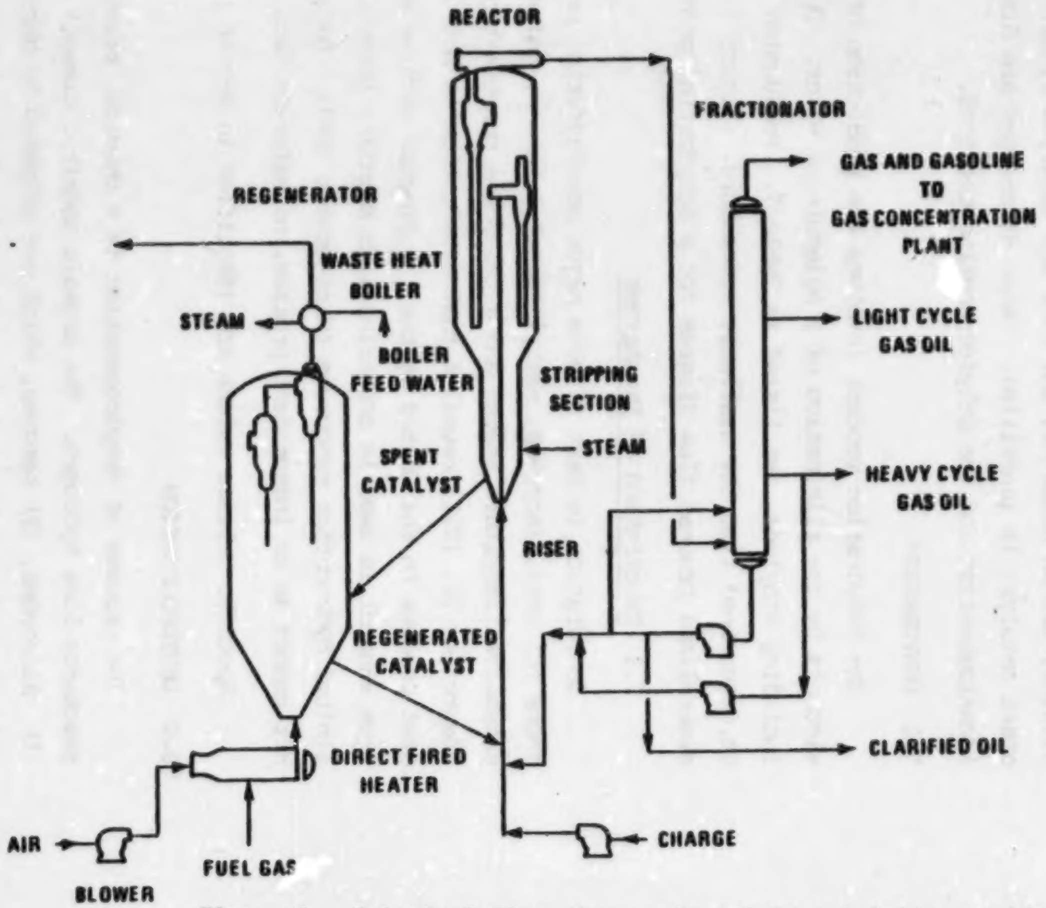

REACTOR
FRACTIONATOR
REGENERATOR
GAS AND GASOLINE TO GAS CONCENTRATION PLANT
WASTE HEAT BOILER
STEAM
BOILER FEED WATER
LIGHT CYCLE GAS OIL
STRIPPING SECTION
STEAM
SPENT CATALYST
HEAVY CYCLE GAS OIL
RISER
REGENERATED CATALYST
DIRECT FIRED HEATER
CLARIFIED OIL
AIR
BLOWER
FUEL GAS
CHARGE

Figure 6. A typical flow diagram for fluid catalytic cracking.

6.1 Description of Discharges

Releases from a typical catalytic cracking process will result as fugitive emissions from pressure relief valves, vents, seals, and equipment leaks. Catalyst regeneration causes intermittent emission of carbon dioxide, carbon monoxide, and coke and catalyst fines. It is assumed that spent catalyst is landfilled. Other discharges are discussed in the dehydrohalogenation and the dehydrogenation sections.

7.0 DEHYDRATION

The dehydration process involves the production of alkenes from alcohols by the elimination of a molecule of water. Dehydration products, including ethylene, are listed in Table 7. Production for 1980 could not be determined from the available literature. Figure 7 presents the generalized process flow diagram for a dehydration process.

7.1 Description of Discharges

Dehydration is part of some major manufacturing processes such as those for urea, isoprene, methyl isobutyl ketone, and mesityl oxide. An extensive literature search and a telephone conversation with E.C. Herrick (September 22, 1981) revealed that dehydration is not used as an independent process in the United States. A process such as ethylene manufacture from ethanol is used in countries with abundant fermentation materials but limited hydrocarbon resources (Kirk-Othmer 1980). Because dehydration is not common as an independent process, no emission data were available.

Specific release values are identified in Versar (1982).

8.0 DEHYDROGENATION

The process of dehydrogenation is a chemical reaction whereby the reactants lose hydrogen. The organic chemical classes concerned are (1) aldehydes, (2) ketones, which are prepared by dehydrogenating alcohols, and (3) olefins, which are prepared from their saturated hydrocarbons.

TABLE 7. DEHYDRATION PRODUCTS

Product	Feedstock	Other Required Processes
Ethylene	Ethyl alcohol	None
Isoprene (2-Methyl-1, 3-butadiene)	Acetone Acetylene	Condensation Hydrogenation
Mesityl oxide (isopropylidene acetone)	Acetone	Condensation
Methyl isobutyl ketone	Acetone Hydrogen	Condensation Hydrogenation
Morpholine	Diethanolamine	None
Urea	Ammonia CO_2	Amination

Source: Herrick et al. 1979a.

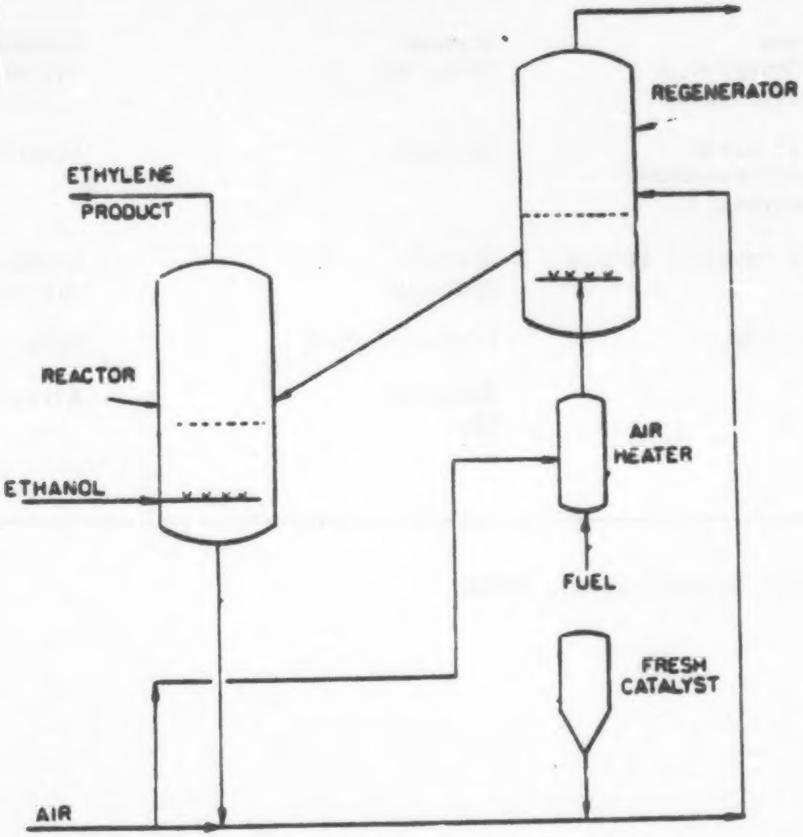

ETHYLENE
PRODUCT
REGENERATOR
REACTOR
ETHANOL
AIR
HEATER
FUEL
FRESH
CATALYST
AIR

Figure 7. Proposed ethanol manufacturing process by dehydration of ethanol.

Source: U.S. Patent.

Table 8 lists the organic chemicals that are manufactured by dehydrogenation (Herrick et al. 1979a). A typical dehydrogenation process diagram is presented in Figure 8.

8.1 Description of Discharges

fugitive emissions - occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains and cooling towers.

dehydrogenation section - pollutants are released when regenerating and purging the catalyst beds as air emissions, wastewater, and spent catalysts. Also air emissions occur from leaks in the reactors.

product cooling - using condensers, partial condensers and oil quenches results in contaminated liquid waste streams and vent gases.

product purification - using caustic scrubbers, degasser and water washes results in contaminated liquid waste streams.

product separation - absorbers, strippers and fractionating columns (both extractive and conventional distillation) result in fugitive and intermittent air emissions, solid tarry matter in bottoms at blowdown, contaminated liquid wastes containing products, and extractive solvents.

steam generation - contaminants released during operation and at cooling towers blowdown.

Quantification of releases is presented in Versar (1982).

9.0 DEHYDROHALOGENATION

In the process of dehydrohalogenation, a hydrogen atom and a halogen atom are removed from one or more feedstocks to obtain a new chemical. In commercial operation, the halogen atom is usually chlorine. A typical dehydrohalogenation train includes a reactor and a purification system. Figure 9 is a typical process flow diagram. The principal organic chemicals manufactured by dehydrohalogenation are listed in Table 9.

TABLE 8. ORGANIC CHEMICALS MANUFACTURED BY DEHYDROGENATION

Product	Amount (kkg)	Feedstock	Other Required Processes
Acetaldehyde	-	Ethyl alcohol	None
Acetone	-	Isopropyl alcohol	None
Linear alkyl benzenes	102.3	Benzenes Linear paraffin	Alkylation
Biphenyl	26.4	Benzene	Condensation
Butadiene	325.0	*n*-Butane	None
Butadiene		Butene-1 Butene-2	None
Cyclohexanone	396.9	Cyclohexanol/cyclohexane	None
2-Isoamylene	-	Isopentane	None
Isoprene	248.6	Isopentane	None
Isoprene		Tertiary amylenes	None
Methyl ethyl ketone	-	Butene-1 Butene-2	Hydrolysis
Methyl ethyl ketone		sec-Butyl alcohol	None
Phenol	Insignificant amts.	Cyclohexane	Ammoxidation
p-Phenyl phenol	-	Benzene Cyclohexane	Condensation
Piperylene	-	*n*-Pentene	None
Propylene	6440.4	Propane	None
Styrene	3394.8	Benzene Ethylene	Alkylation
Styrene		Ethylbenzene	None
Xylenes, mixed	-	Naphtha	None

Source: Herrick et al. 1979a; SRI 1979a.

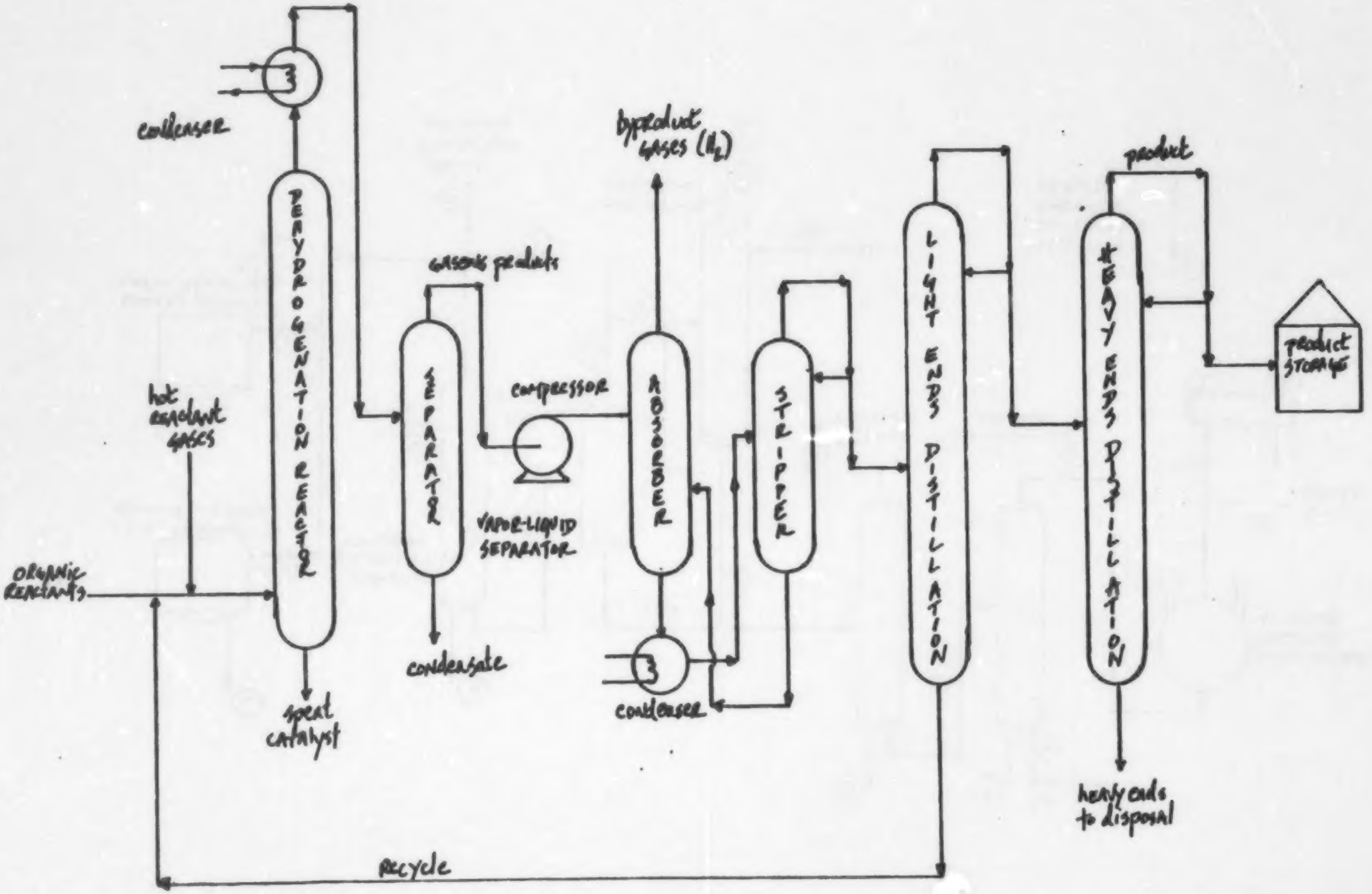

condenser
DEHYDROGENATION REACTOR
hot reactant gases
ORGANIC REACTANTS
spent catalyst
gaseous products
SEPARATOR
VAPOR-LIQUID SEPARATOR
condensate
compressor
byproduct gases (H_2)
ABSORBER
condenser
STRIPPER
LIGHT ENDS DISTILLATION
HEAVY ENDS DISTILLATION
product
PRODUCT STORAGE
heavy ends to disposal
Recycle

Figure 8. Typical dehydrogenation process.

Source: Hydrocarbon Processing, 1973.

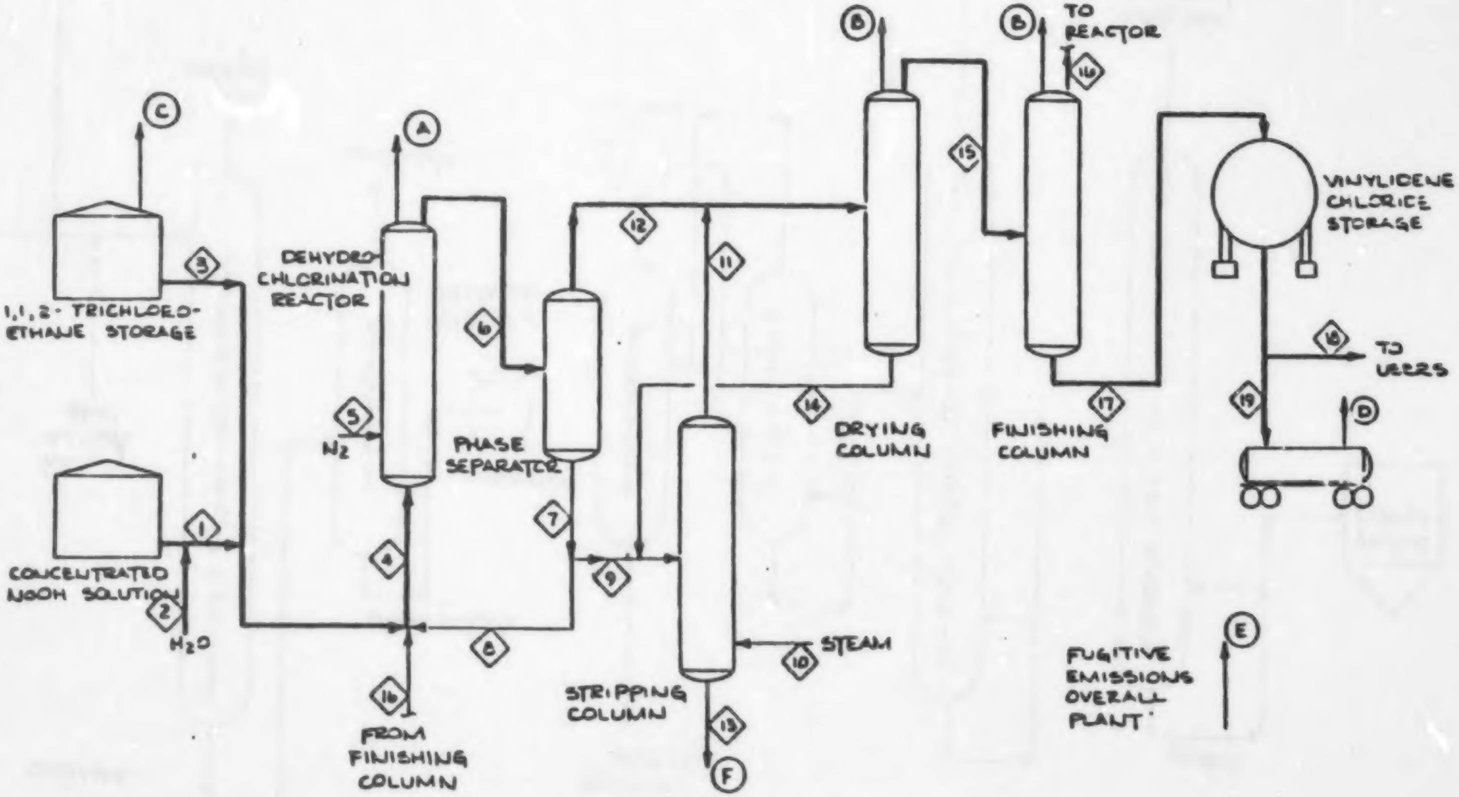

C
3
1,1,2-TRICHLORO-ETHANE STORAGE
1
CONCENTRATED NaOH SOLUTION
2
H2O
A
DEHYDRO-CHLORINATION REACTOR
5
N2
4
16
FROM FINISHING COLUMN
6
8
PHASE SEPARATOR
7
9
12
11
STRIPPING COLUMN
10
STEAM
13
F
B
14
DRYING COLUMN
15
B
TO REACTOR
16
FINISHING COLUMN
17
VINYLIDENE CHLORIDE STORAGE
18
TO USERS
19
D
E
FUGITIVE EMISSIONS OVERALL PLANT

Figure 9. Flow diagram for vinylidene chloride from 1,1,2-trichloroethane.

Source: White 1980b.

TABLE 9. DEHYDROHALOGENATION PRODUCTS AND THEIR PRODUCTION IN 1979[1,2]

Product	Amount (kkg)	Feedstock	Other Required Processes
2-(2,4-Dichlorophenoxy) propionic acid (2,4-DP)	NA	α-chloropropionic acid (2,4-Dichlorophenol)	condensation
N-Isopropyl-N'-phenyl-p-phenylenediamine	28,436*	acetone aniline p-chloronitrobenzene	alkylation condensation hydrogenation
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	NA	α-chloropropionic acid; 4-chlorocresol	condensation
Polycarbonate resins	127,800[3]	bisphenol A phosgene	phosgenation polymerization
Vinyl chloride monomer (VCM)	2,925,000[4]	acetylene ethane chlorine	halogenation oxyhalogenation
Vinyl chloride monomer (VCM)	2,925,000[4]	ethylene chlorine	halogenation oxyhalogenation
Vinyl chloride monomer (VCM) Hydrogen chloride	2,925,000[4]	ethylene dichloride	none
Vinyl chloride monomer (VCM)	2,925,000[4]	naphtha chlorine	halogenation oxyhalogenation
Vinylidene chloride	98,000[5]	vinyl chloride	halogenation

Sources:
[1] Herrick 1979.
[2] USITC 1979.
[3] SRI 1981, 80% of January 1, 1981 capacity.
[4] Chemical & Engineering News, August 3, 1981, 1980 production.
[5] IT Enviroscience 1980, 80% of 1979 reported capacity.

*Includes all substituted p-phenylenediamine.

Note: Dehydrohalogenation is not always the major method of production of these chemicals.

9.1 Description of Discharges

Releases from a typical dehydrohalogenation process occur as fugitive emissions, as reactor off-gases, as column wastes, as catalyst recovery residue, and as storage and handling emissions.

Fugitive - pressure relief valves, pump seals, compressor seals, drains, and cooling towers.

Process - reactor off-gases.

Purification - column vents, column waste streams, filter residue, and catalyst recovery residue.

Storage and Handling - vents from feed tanks, product tanks, and loading.

A quantification of releases from dehydrohalogenation is presented in Versar (1982).

10. ESTERIFICATION

A carboxylic acid is converted into an ester when heated with an alcohol in the presence of a mineral acid, such as sulfuric acid or hydrogen chloride. The process, called esterification, can be batch on continuous, liquid- or vapor-phase. Organic chemicals manufactured by esterification and their amounts produced in 1980 are listed in Table 10. Figure 10 describes a general process flow diagram of an esterification process.

10.1 Description of Discharges

Releases from an esterification process will occur as fugitive and particulate gaseous emissions, liquid wastes, and solid residues. The major sources of contamination are (1) gaseous emissions from the vents on feed tanks and purification columns which pull off excess feedstock and by-products and (2) liquid emissions in waste streams from the reactor and purification column continuing excess feedstock, catalyst, and by-products.

TABLE 10. ESTERIFICATION PRODUCTS

Product	Amount*	Feedstock	Other Required Processes
Acrylic acid & acrylate esters	714,136	propylene alcohols	oxidation
n-Butyl acetate	63,503	acetic acid n-butyl alcohol	
n-Butylbenzyl phthalate	NA	benzyl alcohol n-butyl alcohol phthalic anhydride	
Di-n-butyl phthalate	NA	n-butyl alcohol phthalate anhydride	
Diethyl phthalate	NA	ethyl alcohol phthalic anhydride	
Diheptyl phthalate	NA	heptyl alcohol phthalic anhydride	
Diisodecyl phthalate	NA	isodecyl alcohol phthalic anhydride	
Dimethyl phthalate	NA	methyl alcohol phthalic anhydride	
Dimethyl terephthalate	1,542,214 (feedstock not specified)	methyl alcohol terephthalic acid	
Dimethyl terephthalate		methyl alcohol p-xylene	oxidation
Di-n-octyl phthalate	NA	phthalic anhydride n-octyl alcohol	
Dioctylphthalate (2-ethylhexyl phthalate)	NA	2-ethylhexyl alcohol phthalic anhydride	

Table 10. (Continued)

Product	Amount*	Feedstock	Other Required Processes
Ethyl acetate	94,347	acetic acid ethyl alcohol	
Ethyl acetoacetate	NA	acetic acid	pyrolysis
Ethyl acrylate	NA	ethyl alcohol	oxidation
Isopropyl acetate	19,958	acetic acid isopropyl alcohol	
Methyl acetate	NA	acetic acid methyl alcohol	
Methyl acetonacetate	NA	acetic acid	pyrolysis
Methyl methacrylate	413,676	acetone hydrogen cyanide methyl alcohol	hydrocyanation hydrolysis sulfonation
Methyl methacrylate	NA	isobutylene methyl alcohol	oxidation
p-Oxybenzoic acid α p-Oxybenzoic butyrate	NA	butyl alcohol carbon dioxide phenol	carboxylation
Polyethylene terephthalate	257,640 (barrier resins) 177,808 (film)	ethylene glycol terephthalic acid	polymerization
Triacetate polymer (cellulose triacetate)	NA	acetic acid cellulose	
Tributyrin (glyceral tributyrate)	NA	n-butyric acid α glycerol	

Source: SRI 1981; Herrick et al. 1979.

*SRI lists amounts in plant capacities. For this table, the capacities were multiplied by 0.8.

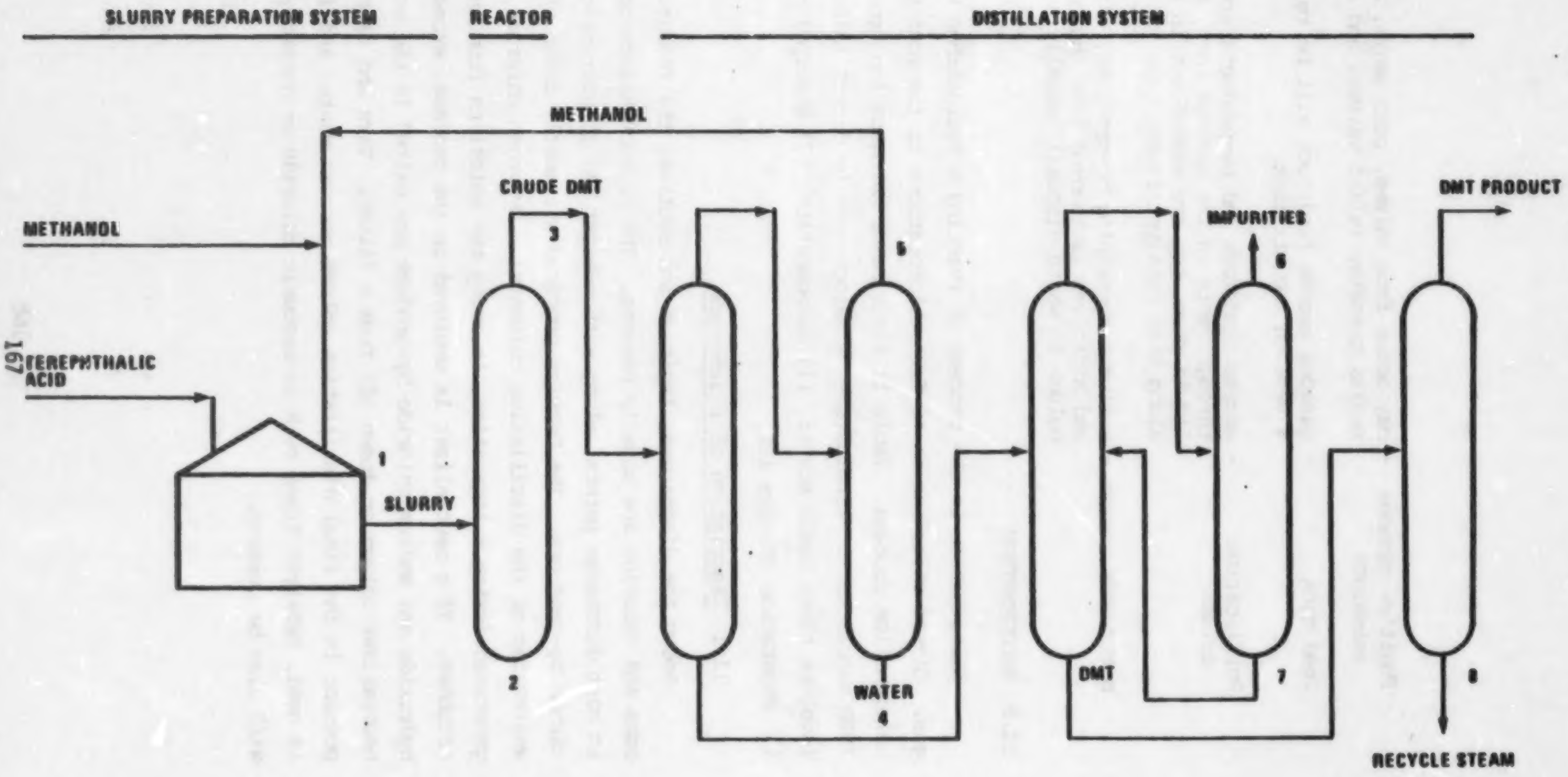

SLURRY PREPARATION SYSTEM
REACTOR
DISTILLATION SYSTEM
METHANOL
METHANOL
CRUDE DMT
3
5
DMT PRODUCT
IMPURITIES
6
TEREPHTHALIC ACID
1
SLURRY
2
WATER
4
DMT
7
8
RECYCLE STEAM

Figure 10. Manufacture of dimethyl terephthalate by esterification.

Fugitive gaseous emissions - may occur from valves, pump seals, compressor seals, pressure relief valves, and drains.

Feed tank - gaseous excess feedstock will be released through a vent on the mix tank.

Purification column - excess feedstock and by-products are released through vents in the gaseous form, and in the liquid form they are washed out in a waste stream along with catalyst fines.

Heavy ends column - a sludge containing by-products, catalyst fines, and additives is removed from the heavy ends column to waste disposal (usually a landfill).

11.0 HALOGENATION

Halogenation is the process of reacting a hydrocarbon with a halogen gas. Direct chlorination to form chlorocarbons is the most widely used halogenation process. Table 11 lists major halogenation products and their 1980 manufacture. Manufacture of halocarbons by direct halogenation involves three basic steps: (1) halogenation, (2) absorption, and (3) separation (Figure 11).

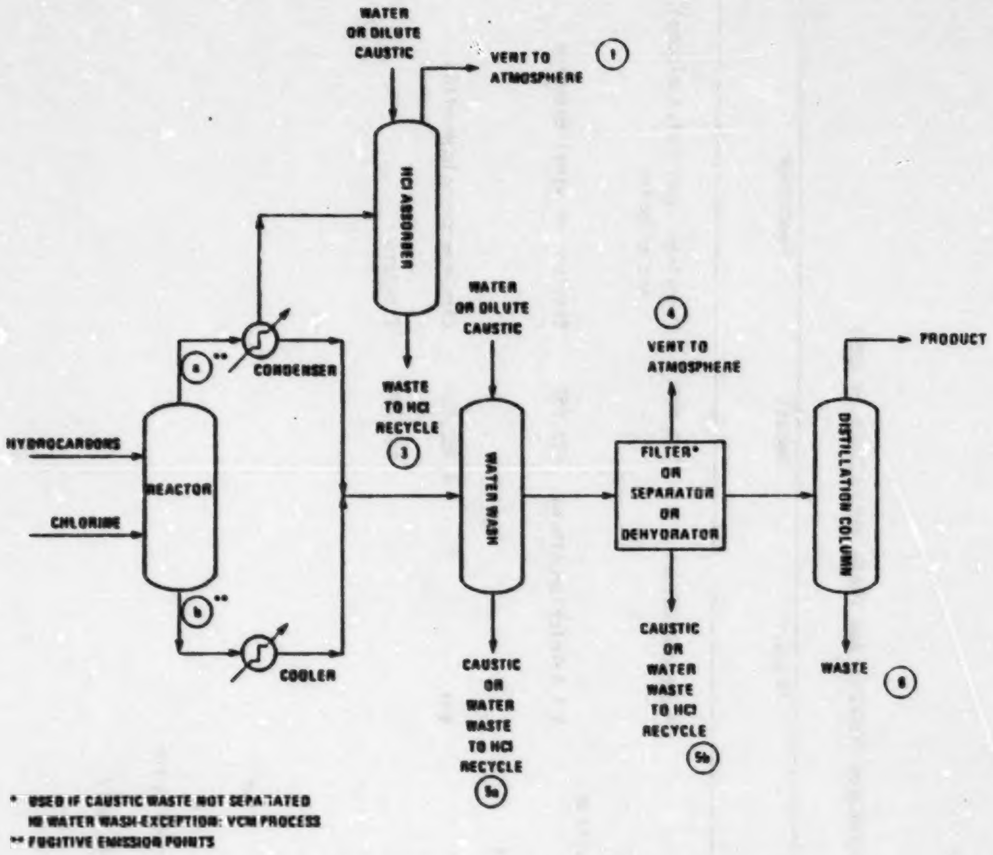
11.1 Description of Discharges

Among the discharges, fugitive and routine, the feedstock hydrocarbons and chlorine are usually present. The product halocarbon is emitted at most discharge points, along with heavier and lighter halogenated hydrocarbon by-products. The heavies produced are mostly drawn off in the final wastewater of the distillation column(s). Hydrogen chloride, which is generated during halogenation, is among the emissions from the HCl scrubber. If a neutralizer is employed in the process, excess sodium hydroxide and sodium chloride by-product are exited in the bottoms of the neutralizer column or drawn off from a filter. Tars and carbon solids are present in the final distillation column bottoms waste, and if a catalyst is used, catalyst fines such as mercuric chloride or antimony trichloride will also be present.

TABLE 11. HALOGENATION PRODUCTS AND THEIR MANUFACTURE IN 1980

Product	Amount (kkg)	Feedstock	Product	Amount	Feedstock
Benzyl chloride	59,874	Toluene	Propylene oxide	533,425	Propylene, tert-butyl alcohol, and chlorine
Carbon tetrachloride	72,574	Carbon disulfide			
	197,040	Methane	1,1,1-Trichloroethane	473,550	Ethylene or vinyl chloride
Chloroacetic acid	35,925	Acetic acid			
Chlorobenzene	228,610	Benzene	VCM	4,762,720	Ethylene-oxyhalogenation
Chloroform	186,880	Methanol		304,814	Ethylene
Dichlorobenzene	39,190	Benzene			
p-Dichlorobenzene	54,068	Benzene			
Ethylene dichloride	6,377,509	Ethylene			
Fluorocarbons	3,661,398	Carbon tetrachloride or methane Hydrofluoric acid			
Methyl chloride	272,155	Methanol			
Methylene chloride	174,179	Methanol			
	72,574	Methane			
	47,174	Methane and methanol			
Perchloroethylene	433,634	Ethylene dichloride or acetylene			
Phosgene	687,646	Carbon monoxide			

'Source: Herrick et al. 1979a and SRI 1981..


WATER
OR DILUTE
CAUSTIC
VENT TO
ATMOSPHERE
①
HCl ABSORBER
WATER
OR DILUTE
CAUSTIC
④
VENT TO
ATMOSPHERE
PRODUCT
a
**
CONDENSER
WASTE
TO HCl
RECYCLE
③
HYDROCARBONS
REACTOR
CHLORINE
WATER WASH
FILTER*
OR
SEPARATOR
OR
DEHYDRATOR
DISTILLATION COLUMN
b
**
COOLER
CAUSTIC
OR
WATER
WASTE
TO HCl
RECYCLE
5a
CAUSTIC
OR
WATER
WASTE
TO HCl
RECYCLE
5b
WASTE
⑥

* USED IF CAUSTIC WASTE NOT SEPARATED IN WATER WASH-EXCEPTION: VCM PROCESS

** FUGITIVE EMISSION POINTS

Figure 11. Halogenation of Hydrocarbon.

Source: Kahn and Hughes 1979.

Quantification of releases from halogenation processes is found in Versar (1982).

12.0 HYDRODEALKYLATION

Hydrodealkylation is the process by which a methyl or larger alkyl groups are removed from hydrocarbon molecules and replaced by hydrogen atoms. Benzene and naphthalene are produced by this process. Table 12 presents the chemicals produced, other processes required, and the feedstock required for the hydrodealkylation process. Figure 12 is a flow diagram for benzene production by the hydrodealkylation process.

12.1 Description of Discharges

Descriptions of discharges are provided for the two major alkylation manufacturing processes, i.e., benzene and naphthalene.

12.1.1 Benzene

Waste streams originate from periodic catalyst regeneration, fugitive emissions from valves and pump seals, discarding spent clay, operating power generation and cooling water systems, gas compressors, and process heaters. Catalyst regeneration in the Detol Process involves occasional burning of coke deposits in a preheated inert gas with controlled quantities of air. Descriptions of the Hydeal process indicate that about 1% of aromatics in the feed may be converted to heavy aromatics such as biphenyl, methyl biphenyls, and fluorene through condensation of aromatic nuclei. These heavy aromatics will most likely be found in the waste stream.

12.1.2 Napthalene

Fugitive emissions of hydrocarbons to the air are expected from distillation units, vents, pumps, seals, and flanges. For processes which use catalysts, catalyst decoking operations can be expected to release particulates, sulfur oxides, and carbon monoxides to the atmosphere. Atmospheric emissions are also expected from process heaters and cooling water treatment.

TABLE 12. ORGANIC CHEMICALS MANUFACTURED BY HYDRODEALKYLATION

Other Processes Required	Product	Feedstock	Amount kkg for 1979
None	Benzene Light hydrocarbon	Aromatic mixtures Hydrogen	NA
None	Benzene	Coke oven light oil	NA
None	Benzene	Toluene	1,498,400
None	Benzene	Xylenes (mixed)	NA
None	Napthalene	Alkylnapthalenes	74,102

Source: Herrick et al. 1979a.

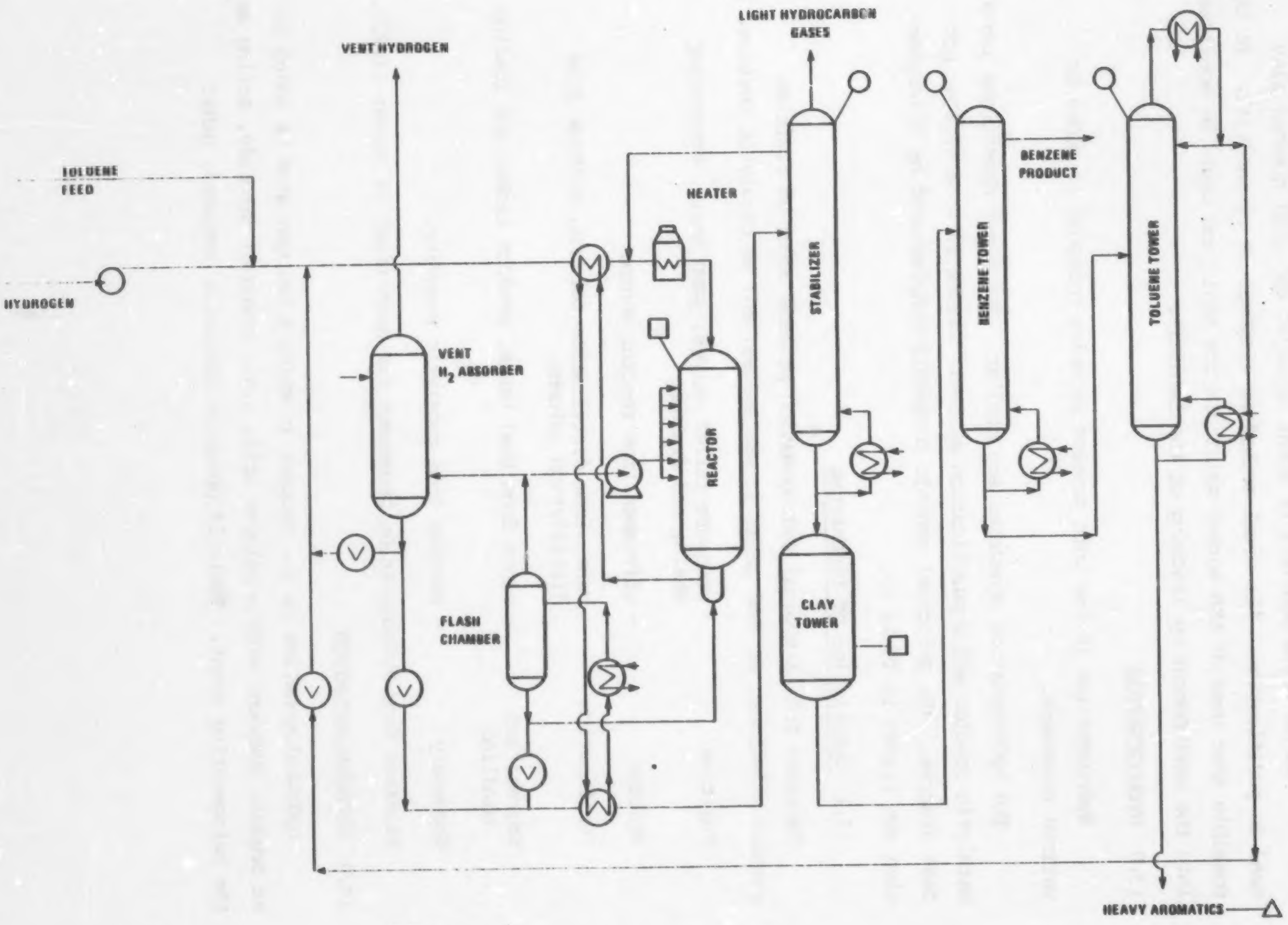

VENT HYDROGEN
TOLUENE FEED
HYDROGEN
VENT H_2 ABSORBER
FLASH CHAMBER
HEATER
REACTOR
LIGHT HYDROCARBON GASES
STABILIZER
CLAY TOWER
BENZENE TOWER
BENZENE PRODUCT
TOLUENE TOWER
HEAVY AROMATICS
NOMENCLATURE: ○ GASEOUS EMISSIONS
□ SOLID WASTE
△ LIQUID WASTE

Figure 12. Benzene production by hydrodealkvlation.

Source: Ehrlich and Chazanow 1973.

Solid waste consists of spent catalyst and acid treated clay used in purification. The usual method of disposal is by landfill. It is possible that some of the sorbed materials are toxic and could be mobilized into the environment by leaching of the landfill.

13.0 HYDROGENATION

Hydrogenation is the unit process in which hydrogen is added to various compounds.

The hydrogenation processes are similar. The major operations are a catalytic reactor and a purification system. Figure 13 is a typical process diagram. The principal organic chemicals manufactured by hydrogenation are listed in Table 13.

13.1 Description of Discharges

Releases from a typical hydrogenation process occur as fugitive gaseous emissions, as vent gases, in wastewater, and as catalytic residue.

Fugitive	- pressure relief valves, pump seals, compressor seals, and drains.
Reactor	- off-gases from reactor vents.
Purification	- vents from distillation columns, bottoms from distillation columns.
Storage and Handling	- vents from feed tanks, product tanks, and loading.
Secondary	- residue from catalytic recovery.

Releases from hydrogenation processes are quantified in Versar (1982).

14.0 HYDROHALOGENATION

Hydrohalogenation is the process in which a halogen atom is added to an organic compound with a halogen acid, e.g., hydrogen chloride, acting as the halogenating agent. Table 14 presents chemicals produced, other

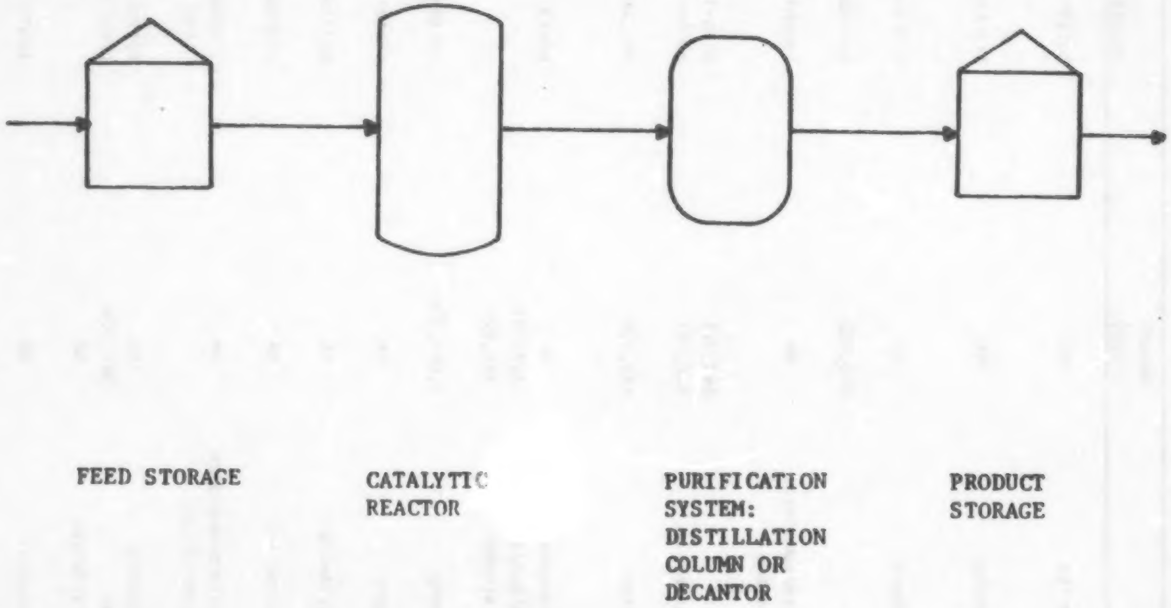

FEED STORAGE
CATALYTIC REACTOR
PURIFICATION SYSTEM: DISTILLATION COLUMN OR DECANTOR
PRODUCT STORAGE

Figure 13. A typical hydrogenation process.

TABLE 13. HYDROGENATION PRODUCTS AND THEIR PRODUCTION IN 1979

Product	Amount (kkg)	Feedstock	Other Required Processes
Adiponitrile	NA	butadiene	ammoxidation halogenation
m-Aminophenol	NA	nitrobenzene	hydrolysis sulfonation
p-Aminophenol	NA	nitrobenzene	acid rearrangement
Aniline	310,402	nitrobenzene	none
1,3-bis(aminomethyl) cyclohexane	NA	isophthalonitrile	none
n-Butanol	344,924	propylene	carbonylation (oxo)
n-Butyraldehyde	427,791	carbon monoxide	
Caprolactam	425,428	toluene, ammonia	acid rearrangement oxidation
Crotonaldehyde	NA	acetaldehyde	condensation dehydration
n-Butyraldehyde	427,791		
n-Butyl alcohol	344,924		
Cyclohexane	1,091,376	benzene	none
Cyclohexanol	NA	phenol	none
Cyclohexylamine	NA	aniline	none
Cyclohexylamine	NA	nitrobenzene	
3,3'-Dichlorobenzidine dihydrochloride	NA	1-chloro-2-nitrobenzene	benzidene rearrangement
2-Ethylhexanol	NA	carbon monoxide	carbonylation (oxo)
n-Butanol	344,924	propylene	
Isobutyraldehyde	NA		
2-Ethylhexanol	NA	acetaldehyde	condensation
Hexamethylenediamine	NA	adiponitrile	none

Table 13. (Continued)

Product	Amount (kkg)	Feedstock	Other Required Processes
Hexamethylenediamine	NA	adipic acid ammonia	ammoxidation
Hydrazobenzene (sym-N,N'-diphenylhydrazine)	NA	nitrobenzene	condensation
Isobutyl alcohol	NA	propylene	carbonylation (oxo)
Isoprene (2-methyl-1,3-butadiene)	246,369	acetone acetylene	condensation dehydration
N-Isopropyl-N'-phenyl-p-phenylenediamine	NA	acetone aniline p-chloronitrobenzene	alkylation condensation dehydrogenation
DL-Methionine	NA	acrolein cyanic acid methyl mercaptan	condensation
2-Methyl-2-butanol	NA	acetone acetylene	condensation
Methyl isobutyl ketone	NA	acetone	condensation dehydration
Sorbitol (1,2,3,4,5,6-hexanehexol)	115,167	corn sugar or corn syrup	none
Toluene diisocyanate (TDI) (80/20-2,4-2,6-TDI)	309,170	phosgene toluene	nitration phosgenation
m-Xylenediamine	NA	isophthalonitrile	none

Sources: Herrick et al. 19791; USITC 1979.

TABLE 14. HYDROHALOGENATION PRODUCTS AND THEIR MANUFACTURE

Product	Amount (kkg)	Feedstock	Other Required Processes
Choline chloride	26,100[2]	ethylene oxide trimethylamine	amination by ammonolysis, condensation
Ethyl chloride	264,000[2]	ethylene	
Isoprene	248,560*[2]	formaldehyde isobutylene	condensation pyrolysis
Methyl bromide	16,640[3]	methanol	
Methyl chloride	209,900[2]	methanol	
1,1,1-Trichloroethane	324,900[2]	vinyl chloride	halogenation
Vinyl chloride monomer	108,880[1]	acetylene	

Source: Herrick et al. 1979a.
[1] SRI 1981.
[2] USITC 1979.
[3] USITC 1977.

*Assumes 100% by pyrolysis.

processes required, required feedstock, and production volumes for products that can be manufactured by the hydrohalogenation process.

A typical hydrohalogenation process (the manufacture of vinyl chloride monomer using hydrogen chloride and acetylene as feedstock) is shown in Figure 14.

14.1 Description of Discharges

Releases from a typical hydrohalogenation process will result as fugitive emissions from process pumps, compressor seals, process valves, pressure relief valves, cooling towers, and drains. When process pressures are higher than cooling water pressures, VOC can leak into the cooling and escape as a fugitive emission from the cooling towers (White 1980b). Pollutants are also released from purging catalyst beds and catalysts regeneration. Waste is also generated from the removal of spent catalysts. The disposal of catalyst residue in landfills and the combustion of organic wastes are sources of emissions.

Production separation and purification result in fugitive and intermittent emissions, and heavy polymeric matter (Faith et al. 1965). Emissions can occur when wastewater from process sources is sent to wastewater treatment systems and the VOC is desorbed.

Specific releases from hydrohalogenation are quantified in Versar (1982).

15.0 HYDROLYSIS AND HYDRATION

Hydrolysis is the process by which an organic feedstock is reacted with water to form one or more new chemical compounds. The reaction occurs at moderately high temperatures and pressures, 150 to 500°C and 60 to 100 atm, respectively. The reactor is usually a catalytic bed, containing ion-exchange catalysts such as phosphoric acid in diatomaceous earth or

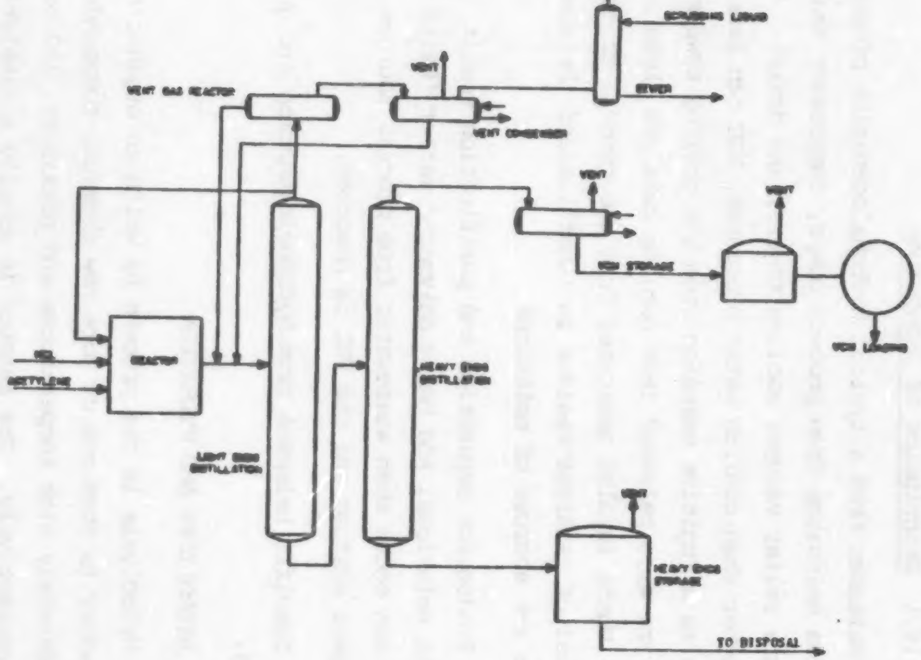

VENT
SCRUBBING LIQUID
VENT
VENT GAS REACTOR
SEWER
VENT CONDENSER
VENT
VENT
VCM STORAGE
HCL
REACTOR
ACETYLENE
HEAVY ENDS DISTILLATION
VCM LOADING
LIGHT ENDS DISTILLATION
VENT
HEAVY ENDS STORAGE
TO DISPOSAL

Figure 14. **A typical hydrohalogenation process: manufacture of vinyl chloride from acetylene and hydrogen chloride.**

Source: Carpenter 1974.

catalytically active silicic acid. Hydrolysis products and their 1980 production levels are found in Table 15.

A typical hydrolysis process is shown in Figure 15.

15.1 Description of Discharges

Releases from a hydrolysis process will occur as fugitive and particulate gaseous emissions and liquid wastes. The major sources of contamination are (1) gaseous emissions from vents on the reactor, scrubber, and distillation columns which pull off excess feedstock and by-products, (2) cooling water contamination from mixing in the condensers with the distillation column overhead, and (3) liquid emissions in waste streams from the final product purification system containing excess feedstock and by-products.

Fugitive gaseous emissions - may occur from valves and process pumps; are released from contaminated cooling water supply.

Reactor - gaseous excess feedstock will be released through a vent on the reactor.

Separator - excess feedstock and by-products are released through vents in the gaseous form.

Scrubber - excess feedstock and by-products are released through vents in the gaseous form, and in the liquid form they are washed out in a waste stream.

Dehydration - excess feedstock and by-products are released through a vent in the gaseous form.

Light ends column - light impurities are released in the gaseous form through a vent.

Final product column - excess feedstock and by-products are released through a vent in the gaseous form, and in the liquid form they are washed out in a waste stream.

Specific releases from this process are quantified in Versar (1982).

TABLE 15. HYDROLYSIS PRODUCTS AND THEIR PRODUCTION IN 1980

Product	Amount[a] (kkg)	Feedstock	Other Required Processes
Acetic acid, methanol	711,233	Methyl acetate	
Acrylamide	54,431	Acrylonitrile	
Alcohols, mixed linear sulfate ammonium salt sodium salt triethanolamine salt unspecified salts	NA	Fatty alcohols, sulfur trioxide	sulfonation
Alkylbenzene sulfonate	NA	Alkylbenzenes, sulfur trioxide	sulfonation
m-Aminophenol	NA	Nitrobenzene	hydrogenation sulfonation
sec-Butyl alcohol	299,371 (feedstock not specified)	Butylene	sulfonation
sec-Butyl alcohol		Butene-1/butene-2	
Epichlorohydrin	170,551	Allyl chloride, hypochlorous acid	chlorohydrination
Ethyl alcohol	NA	Ethylene	
Ethyl alcohol, ethyl ether	23,224	Ethylene	
Ethylene glycol	1,952,262	Ethylene oxide	
Ethylene oxide, ethylene glycol	2,414,926	Ethylene	oxidation
Formic acid, sodium formate	27,215	Carbon monoxide, sodium hydroxide	carbonylation
Formic acid	27,215	Carbon monoxide (methanol recycled)	carbonylation condensation
Glycerin	14,515	Allyl alcohol, peracetic acid	epoxidation
Acetic acid	14,515	Peracetic acid	
Glycerine (glycerol)	36,287	Propylene ⟶ Allyl chloride ⟶ Epichlorohydrin	chlorohydrination halogenation

Table 15. (Continued)

Product	Amount* (kkg)	Feedstock	Other Required Processes
Isopropyl alcohol	1,025,119	propylene	sulfonation
Isopropyl alcohol		propylene	
Maleic acid(cis-1,2-ethylene-dicarboxylic acid)	NA	maleic anhydride	
Methyl ethylketone	252,197	butene-1/butene-2	dedhydrogenation
Methyl methacrylate monomer	413,676	acetone, hydrogen cyanide, methanol	esterification hydrocyanation sulfonation
2-naphthol	NA	naphthalene	sulfonation
Pentachlorophenol	NA	hexachlorobenzene	
Phenol	NA	monochlorobenzene	
Phenol	NA	benzene, sulfuric acid	sulfonation
Phenol	NA	benzene, hydrogen chloride	oxyhalogenation
Phenol, acetone	1,416,297 1,909,805	benzene, propylene	acid cleavage alkylation oxidation
Propylene glycol (1,2-dihydroxypropane)	315,700	propylene oxide	
Propylene oxide	533,425 NA	propylene tert-butyl alcohol (recycled chlorine)	chlorohydrination halogenation
Propylene oxide	533,425	propylene, chlorine solution	chlorohydrination
2,4,5-trichlorophenol	NA	benzene, methanol, sodium hydroxide	halogenation

Source: SRI 1981; Herrick et al. 1979a.

*SRI lists amounts in plant capacities. For this table, the capacities were multiplied by 0.8.

Note: The production data shown do not necessarily imply that hydrolysis in combination with the other required processes is the only product manufacturing train in commercial use.

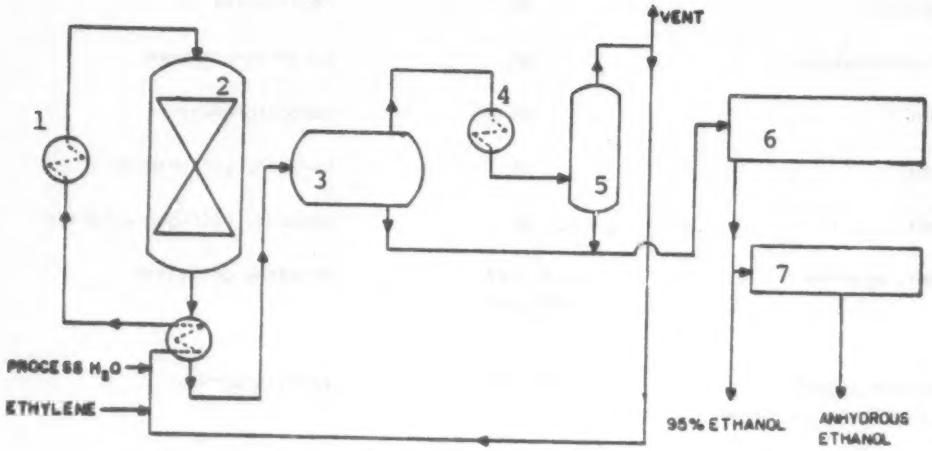

VENT
1
2
3
4
5
6
7
PROCESS H_2O
ETHYLENE
95% ETHANOL
ANHYDROUS ETHANOL

Figure 15. General hydrolysis process.

1) heater

2) reactor

3) separator

4) cooler

5) scrubber

6) distillation column

7) dehydrator

16.0 NITRATION

Nitration is the process in which nitrogen is introduced into a hydrocarbon by the use of nitric acid.

Table 16 lists the principal organic chemicals manufactured by nitration. Figure 16 shows a nitration process sequence, the manufacture of nitrobenzene from nitric acid and benzene.

16.1 Description of Discharges

Emissions from a typical nitration process are released to the three media of air, land, and water at different stages in the process.

Reactor - volatile organic emissions, nitrogen oxide emissions, and sulfuric acid fumes.

Washer/Neutralizer- nitrobenzene, nitrated phenols, sodium sulfate, and sodium carbonate combined in the wastewaters; purges of volatile organics.

Sulfuric acid regeneration acid - purges of nitrogen oxide, sulfuric acid fumes, and volatile organics.

Product Upgrading - purges of volatile organics from condensers; possibility of nitro-substituted aromatic compounds in the heavy ends.

Storage Vessels - storage of feedstock and product result in volatile organic compounds emissions.

Fugitive Emissions- occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drain, and cooling towers.

Secondary Emissions - occur from the handling and disposal of process waste liquid.

Specific releases are quantified in Versar (1982).

17.0 OXIDATION

The unit process of oxidation is the chemical reaction of organic compounds with oxygen to introduce one or more oxygen atoms into the compound, and/or to remove hydrogen atoms from the compound.

TABLE 16. NITRATION PRODUCTS[1] AND THEIR MANUFACTURE IN 1980[2]

Product	Amount (kkg)	Feedstock	Other Required Processes
o-Aminophenol	NA[3]	Phenol	Amination by reduction
4,6-Dinitro-o-cresol	NA[3]	Cresol	None
2,4-Dinitrophenol	NA[3]	Phenol	None
2,4-Dinitrotoluene	NA[3]	Toluene	None
2,4-(and 2,6)			
Dinitrotoluene	NA[3]	Toluene	None
Nitrobenzene	610,176	Benzene	None
o-Nitrophenol	NA[3]	Phenol	None
p-Nitrophenol	29,056	Phenol	None
∿-Nitrophenol	NA[3]	Toluene	None
o-Nitrotoluene	NA[3]	Toluene	None
p-Nitrotoluene	NA[3]	Toluene	None
Toluene diisocyanate (TDI)	259,688	Phosgene	Hydrogenation
(80/20 2,4=2,6-TDI)		Toluene	Phosgenation

Sources: 1. Herrick et al. 1979a.
2. SRI 1981. Production levels are assumed to be 80% of plant nameplate capacity. It may not be assumed, however, that the products are solely manufactured by a nitration process.
3. SRI 1981. No quantitative data are available. However, a list of manufacturers is provided.

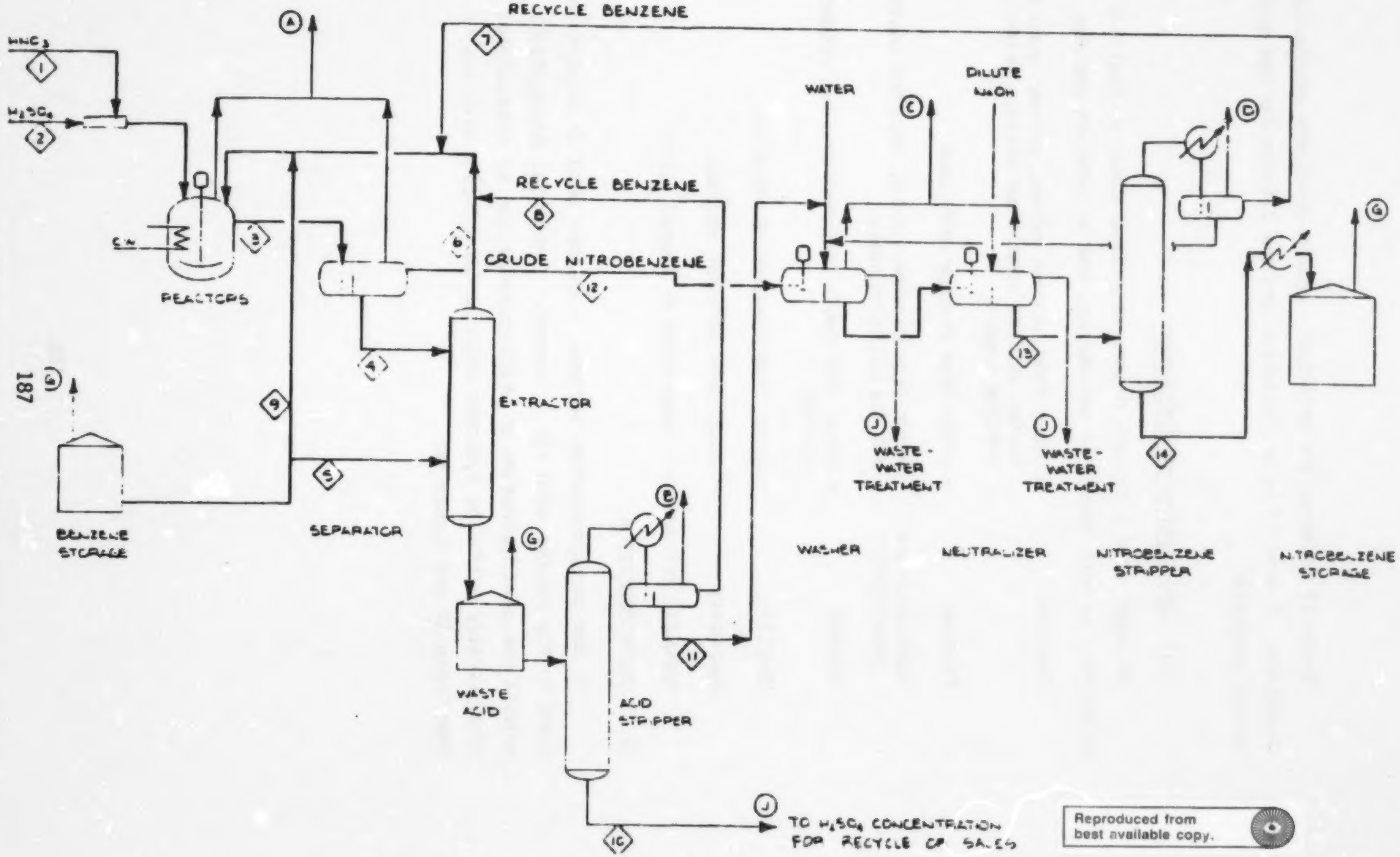

HNO3
1
H2SO4
2
C.W.
REACTORS
3
A
RECYCLE BENZENE
7
RECYCLE BENZENE
8
6
CRUDE NITROBENZENE
12
4
9
5
G
BENZENE STORAGE
SEPARATOR
EXTRACTOR
G
WASTE ACID
B
ACID STRIPPER
11
10
J
TO H2SO4 CONCENTRATION FOR RECYCLE OR SALES
WATER
C
DILUTE NaOH
J
WASTE - WATER TREATMENT
J
WASTE - WATER TREATMENT
13
WASHER
NEUTRALIZER
C
14
NITROBENZENE STRIPPER
G
NITROBENZENE STORAGE

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Figure 16. Process flow diagram for manufacture of nitrobenzene.

Source: White 1980c.

Table 17 presents the principal organic chemicals manufactured by oxidation. Figure 17 is an oxidation process diagram for the production of maleic anhydride.

17.1 Description of Discharges

Releases from a typical oxidation process occur as fugitive gaseous emissions, as vent gases, in wastewater, and as catalyst residue.

Fugitive - occur from process valves, process pump seals, relief valves, compressor seals, drains, and cooling towers.

Process - occur from reactor off-gases.

Separation and purification - occur from scrubber vents, scrubber wastewater, and distillation vents.

Storage - occur from feed, intermediate, and product storage.

Handling - occur from transfer of organics.

Secondary - occur from catalyst residue.

Specific releases are quantified in Versar (1982).

18.0 OXYHALOGENATION

In the oxyhalogenation process, a halogen acid is catalytically oxidized to the halogen with air or oxygen. Commercial applications of the process use oxychlorination in which chlorination is accomplished by catalytically oxidizing hydrogen chloride to chlorine with air or oxygen (see Table 18 and Figure 18).

TABLE 17. OXIDATION PRODUCTS AND THEIR PRODUCTION IN 1979

Product*	Amount (kkg)	Feedstock	Other Required Processes
Acetaldehyde	479,906[1]	ethylene	none
Acetic acid	1,481,044	n-butenes	alkylation
Acetic acid	1,481,044	light naphtha	none
Acetic acid	1,481,044	acetaldehyde	none
Peracetic acid	NA		
Acetic acid	1,481,044	n-butane	none
Terephthalic acid	NA	p-xylene	
Acetone	478,091[1]	benzene	none
Phenol	36,553	propylene	
Acetylene	NA	hydrocarbons	cracking
Ethylene	NA	(C_1-C_8)	
Acrolein	NA	propylene	none
Acrylic acid	275,788		
Acetaldehyde	NA		
Acrylic acid	328,720[2]	propylene	esterification
Acrylic esters		alcohols	
Adipic acid	682,160[3]	cyclohexane	none
Adipic acid	682,160[3]	cyclohexyl alcohol	none
Anthraquinone	18,897[1]	anthracene	none
Benzoic acid	34,946	toluene	none
Tert-butyl alcohol	NA	isobutane	none
Caprolactam	428,828	cyclohexane	Beckmann rearrangement oxidation
Caprolactam	428,826	toluene	acid rearrangement hydrogenation
Cyclohexanone	739,200[4]	cyclohexane	none
Cyclohexyl alcohol			

Table 17. (Continued)

Product*	Amount (kkg)	Feedstock	Other Required Processes
Dimethyl terephthalate	653,600[3]	methanol p-xylene	esterification
Ethyl acrylate	143,328	ethyl alcohol propylene	esterification
Ethylene oxide	8,618[5]	ethylene	none
Ethylene oxide/ ethylene glycol	8,618[5]/2,144,866	ethylene	hydrolysis
Formaldehyde	2,708,479	methanol with silver catalyst	none
Formaldehyde	2,708,479	methanol with metal oxide catalyst	none
Formaldehyde	NA	dimethyl ether	none
Formic acid	8,165[5]	light hydrocarbons	none
Fumaric acid (trans-1,2-ethylene dicarboxylic acid)	23,078	benzene	isomerization
Glycerine	47,200[6]	propylene	none
Isophthalic acid	NA	m-xylene	none
Maleic anhydride	146,614	butadiene (and other C_4 hydrocarbons)	none
Maleic anhydride	146,614	benzene	none
Maleic anhydride	146,614	butene-1, butene-2, butadiene (if present)	none
Methyl methacrylate	422,241	isobutylene, methanol	esterification
Pelargonic acid Caproic acid Azeliac acid	NA NA NA	oils (tall, red, soybean)	ozonolysis
Pelargonic acid Undecanoic acid Tridecanoic acid	NA NA NA	α-olefins	ozonolysis

Table 17. (Continued)

Product*	Amount (kkg)	Feedstock	Other Required Processes
Phenol	1,315,715	cumene	acid cleavage
Acetone	782,254		
Phenol	36,553	benzene, propylene	acid cleavage
Acetone	NA		alkylation
Phenol	36,553	cyclohexane	dehydrogenation
Hydrogen	NA		
Phthalic anhydride	215,459[5]	naphthalene	none
Phthalic anhydride	215,459[5]	o-xylene	alkylation
Phthalic dianhydride (1,2,4,5-benzenetetra-carboxylic-1,2,4,5-dianhydride)	NA	pseudocumene	alkylation
Suberic acid	NA	cyclic olefins	ozonolysis
Dodecanoic acid	NA		
Terephthalic acid	1,051,200[3]	p-xylene	none
Tetrahydrofuran,	NA	furan	condensation
2,3,4,5-tetracarboxylic dianhydride	NA	maleic anydride	
Tetramethylthiuram disulfide (thiuram) [bis(dimethylthiocarbamoyl)disulfide]	NA	ammonia, carbon disulfide, dimethylamine, hydrogen peroxide	condensation
Trimellitic anhydride (1,2,4-benzene-tricarboxylic acid, 1,2-anhydride)	NA	pseudocumene	none

Source: Hedley et al. 1979a, USITC 1980.

Note: Oxidation is not always the major method of production of these chemicals.

*Some oxidation processes have more than one product.

[1] Shreve 1967, production in 1964.
[2] White 1980d, 80% of 1976 capacity of both products.
[3] White 1980d, 80% of 1978 capacity.
[4] White 1980d, 80% of 1979 capacity of both products.
[5] Faith 1965, production in 1963.
[6] White 1980d, 80% of 1977 capacity.

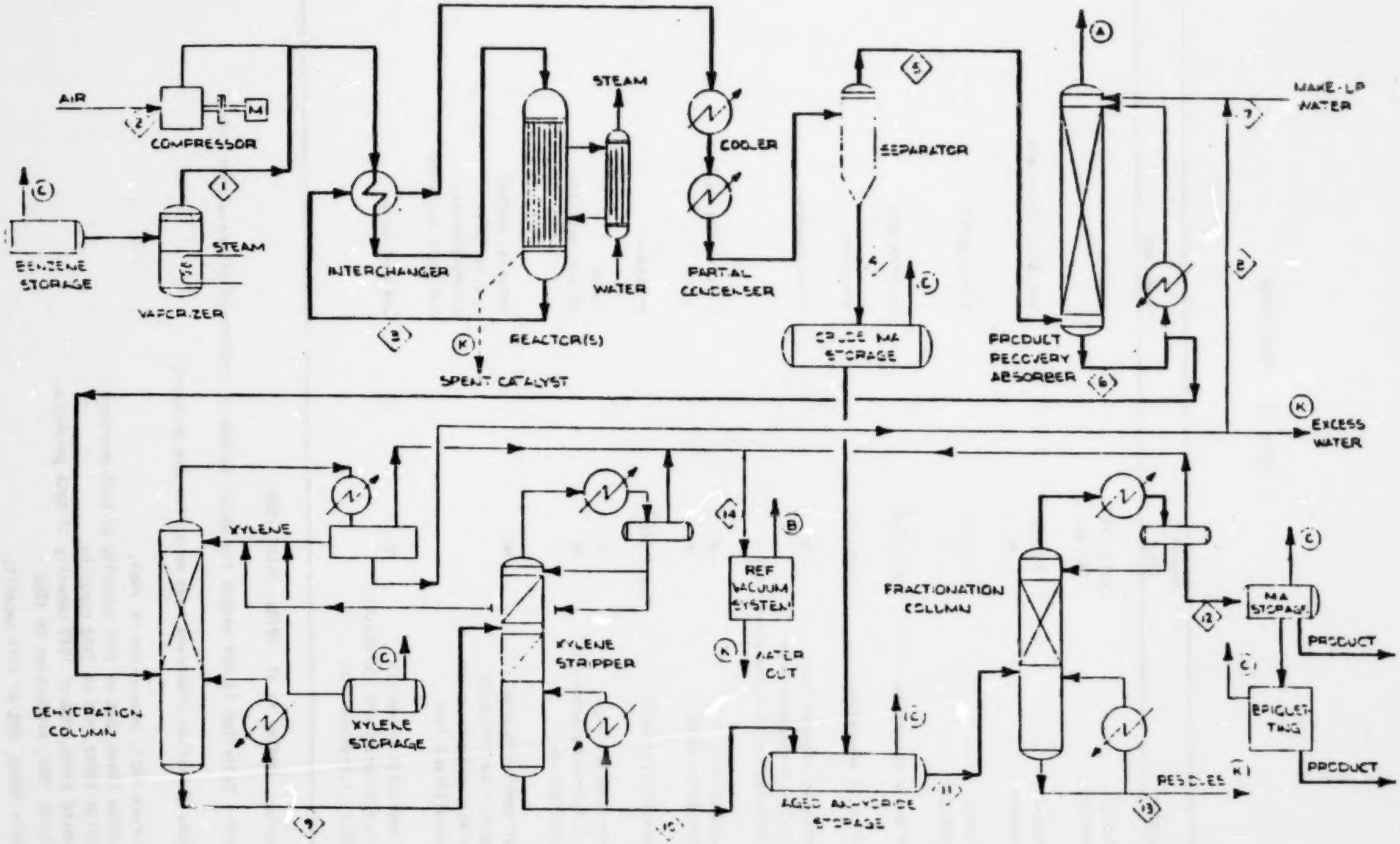

AIR
2
COMPRESSOR
M
C
BENZENE STORAGE
VAPORIZER
STEAM
1
INTERCHANGER
3
K
SPENT CATALYST
REACTOR(S)
STEAM
WATER
COOLER
PARTIAL CONDENSER
5
SEPARATOR
4
C
CRUDE MA STORAGE
A
PRODUCT RECOVERY ABSORBER
6
7
MAKE-UP WATER
8
K
EXCESS WATER
XYLENE
DEHYDRATION COLUMN
9
C
XYLENE STORAGE
XYLENE STRIPPER
10
14
B
REF VACUUM SYSTEM
K
WATER OUT
C
AGED ANHYDRIDE STORAGE
11
FRACTIONATION COLUMN
12
13
RESIDUES
K
C
MA STORAGE
PRODUCT
C
BRIQUETTING
PRODUCT

Figure 17. Process flow diagram for model plant of uncontrolled maleic anhydride manufacture by benzene oxidation.

Source: White 1980d.

Table 18. Oxyhalogenation Products[1] and Their Manufacture in 1979[2]

Product	Amount (kkg)	Feedstock	Other Required Processes
Ethylene dichloride	5,350,000	Ethylene	none
Perchloroethylene	350,640	Any C_2	Halogenation
Trichloroethylene	144,892	Chlorocarbon mixture	Catalytic cracking
Phenol	36,552[3]	Benzene, HCl	Hydrolysis
Vinyl chloride monomer	NA	Ethane Chlorine	Dehydrohalogenation Halogenation
Vinyl chloride monomer	1,823,440[4]	Ethylene Chlorine	Dehydrohalogenation Halogenation
Vinyl chloride monomer	NA	Naptha Chlorine	Dehydrohalogenation Halogenation

Sources:

[1] Herrick et al. 1979a.

[2] USITC 1979. Total production from all processes.

[3] Includes all phenol produced with the exception of phenol from cumene, production, coke ovens, and gas-retort ovens.

[4] SRI 1981. Production levels are assumed to be 80% of plant nameplate capacity.

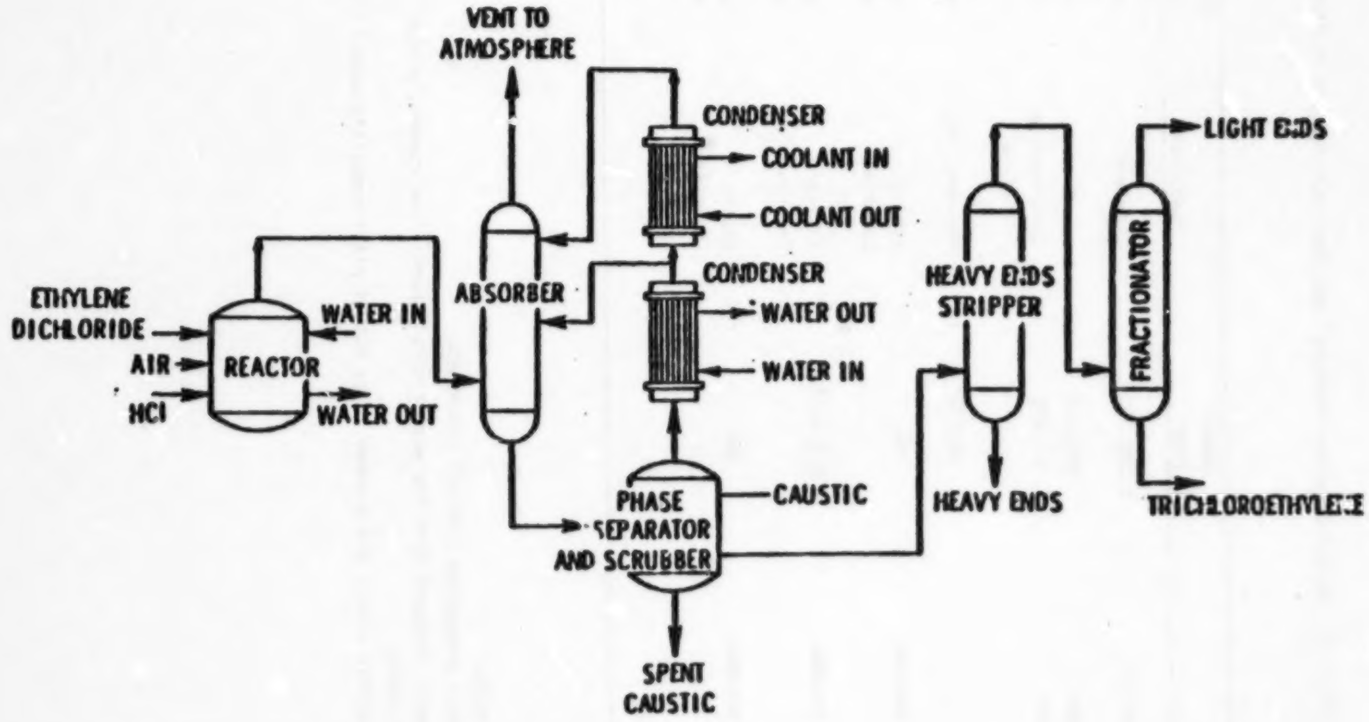

VENT TO ATMOSPHERE
CONDENSER
COOLANT IN
COOLANT OUT
CONDENSER
WATER OUT
WATER IN
LIGHT ENDS
ETHYLENE DICHLORIDE
AIR
HCl
REACTOR
WATER IN
WATER OUT
ABSORBER
HEAVY ENDS STRIPPER
FRACTIONATOR
PHASE SEPARATOR AND SCRUBBER
CAUSTIC
HEAVY ENDS
TRICHLOROETHYLENE
SPENT CAUSTIC

Figure 18. Manufacture of trichloroethylene by oxychlorination.

SOURCE: Khan and Hughes 1979.

18.1 Description of Discharges

Oxyhalogenation manufacturing process emissions usually consist of hydrocarbons. These may be feedstock, impurities in the feedstock, products, and by-products.

Emissions from two typical oxyhalogenation manufacturing processes may be classified under the headings of fugitive, process, secondary, and storage and handling:

Fugitive emissions	- occur from pressure relief valves, flanges, pump seals, valve steams, and compressors. When process pressures are higher than cooling water pressure, VOC can leak into the cooling water and escape as a fugitive emission from the cooling tower.
Process emissions	- from absorber vents which release inert gases from the oxygen, chlorine, hydrogen chloride, and other feeds; drying column releases or non-condensable gases; and neutralizer vents.
Secondary emissions	- from wastewater containing VOC in the waste treatment system and from the combustion of tars in the incinerator.

Specific releases from this process are quantified in Versar (1982).

19.0 PHOSGENATION

Phosgenation is the process in which phosgene reacts with an amine to form an isocyanate or in which phosgene reacts with an alcohol to form a carbonate.

Table 19 lists the chemicals produced by phosgenation. Figure 19 is a flow diagram for diisocyanate production by the phosgenation process.

19.1 Description of Discharges

Waste streams will contain fugitive emissions from valves, gas compressors, wastewater treatment systems, and cooling water systems.

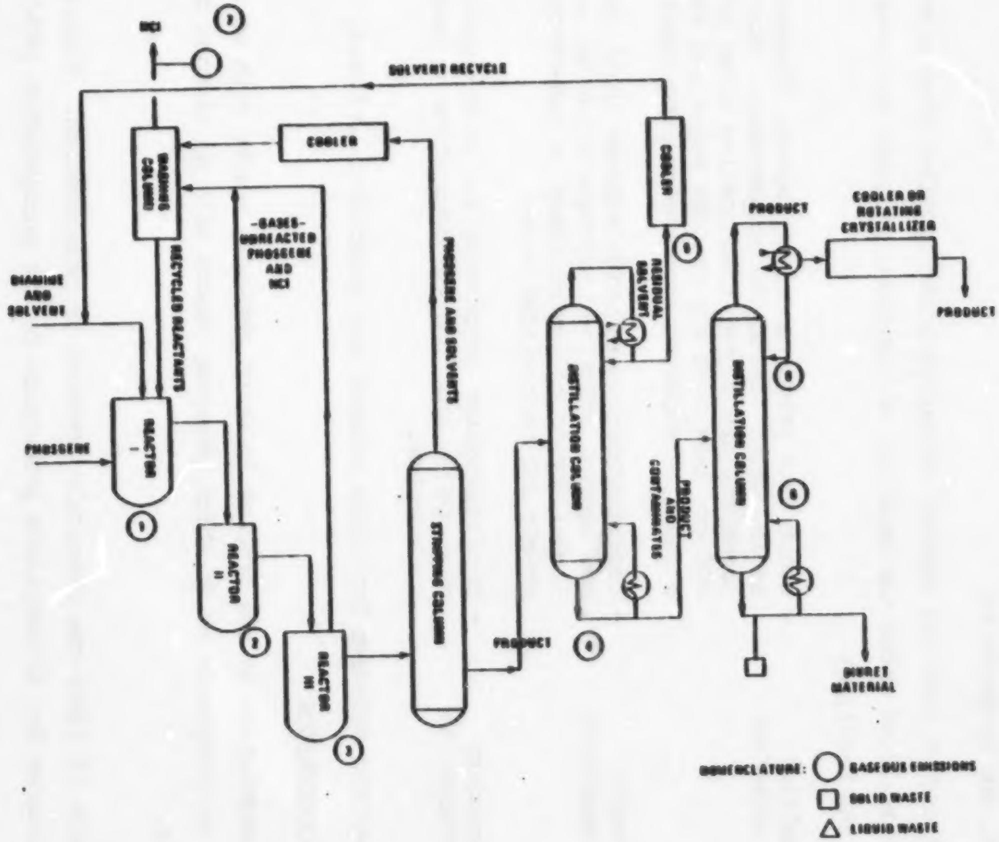

HCl
SOLVENT RECYCLE
COOLER
WASHING COLUMN
RECYCLED REACTANTS
-GASES- UNREACTED PHOSGENE AND HCl
DIAMINE AND SOLVENT
PHOSGENE
REACTOR I
REACTOR II
REACTOR III
PHOSGENE AND SOLVENTS
STRIPPING COLUMN
PRODUCT
DISTILLATION COLUMN
RESIDUAL SOLVENT
COOLER
PRODUCT AND CONTAMINATES
DISTILLATION COLUMN
PRODUCT
COOLER OR ROTATING CRYSTALLIZER
PRODUCT
BIURET MATERIAL
NOMENCLATURE:
GASEOUS EMISSIONS
SOLID WASTE
LIQUID WASTE

Figure 19. Flow diagram for diisocyanate production.

Source: Adapted from Pistor et al. 1977 and Nersasian 1975.

TABLE 20. ORGANIC CHEMICALS MANUFACTURED IN POLYMERIZATION[1]

Products	Annual Production (kkg 1979)[2]	Reactants	Other Required Processes
Acrylic resins	517,856	acrylonitrile	
Acrylonitrile-butadiene-styrene resins (ABS)	567,665	acrylonitrile butadiene styrene	
Epoxy resin	217,595	bisphenol A epichlorohydrin	
Ethylene-propylene copolymer resins	176,389	ethylene or propylene	
Ethylene-vinyl acetate copolymer resins	-	ethylene vinyl acetate	
Polyamide resins (Nylon 6)	131,091	caprolactum	
Polyamide resins (Nylon 66)		adipic acid hexamethylene diamine	
Polybutadiene[3]	9,281	butadiene	
Polybutadiene-acrylonitrile (NBR)	73,253	acrylonitrile butadiene	
Polybutenes	-	butene-1/butene-2	
Polycarbonate resins	-	bisphenol A phosgene	dehydrohalogenation phosgenation
Polychloroprene (neoprene)	83,163	chloroprene	
Polyester resins (saturated)	267,660	glycols polybasic acids styrene	
Polyester resins[4] (unsaturated)	536,036	glycols styrene unsaturated dibasic acids	
Polyether glycols	830,497	ethylene oxide propylene oxide	
Polyether glycols		ethylene oxide propylene oxide alcohols	

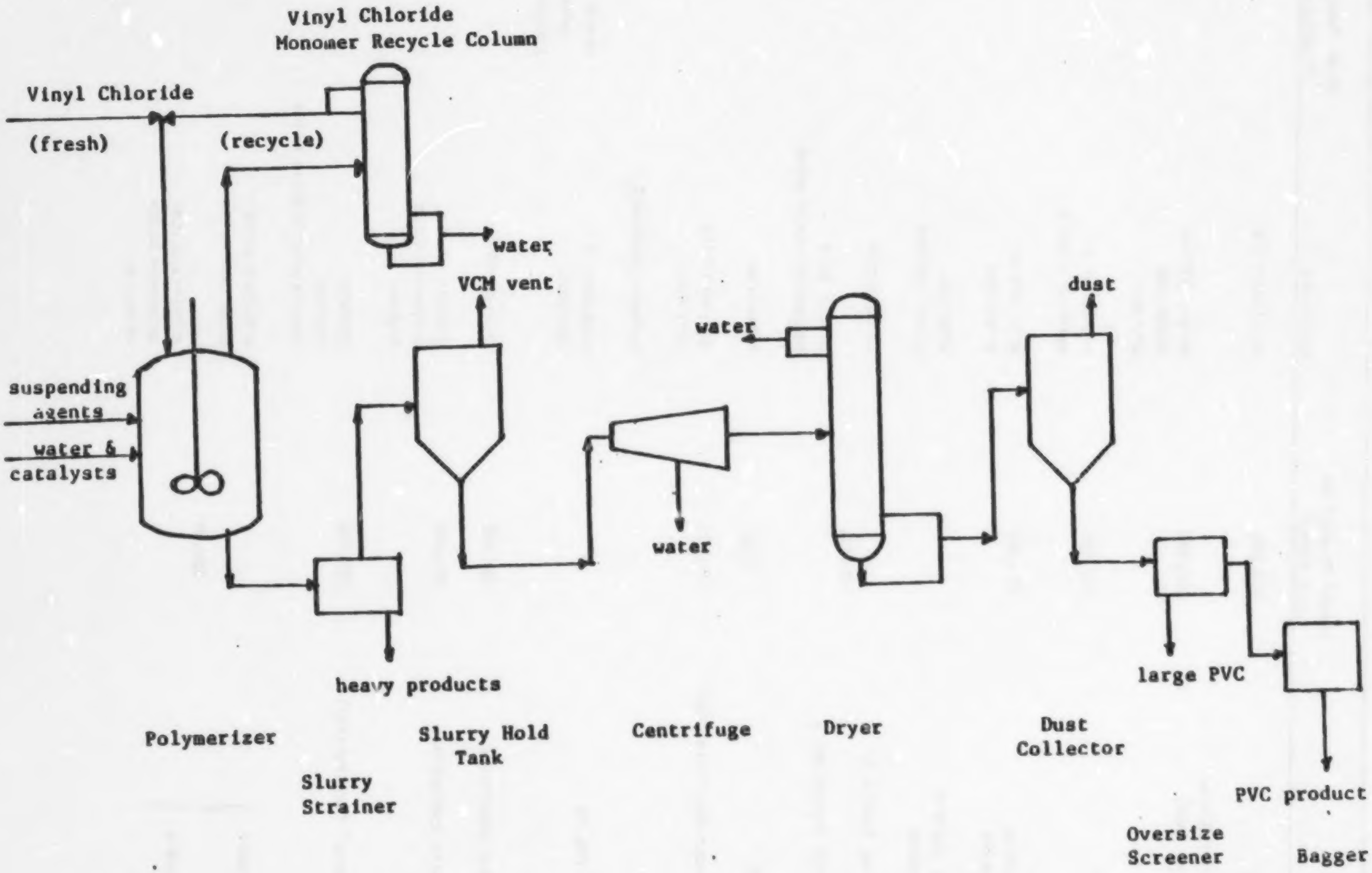

Vinyl Chloride
Monomer Recycle Column
Vinyl Chloride
(fresh)
(recycle)
water
VCM vent
suspending agents
water & catalysts
water
dust
water
heavy products
large PVC
Polymerizer
Slurry Strainer
Slurry Hold Tank
Centrifuge
Dryer
Dust Collector
Oversize Screener
PVC product
Bagger

Figure 20. Process flow diagram for the manufacture of polyvinyl chloride.

go to agitated thinning tanks which release a liquid waste caused by spills and washout. Resins for moldings are dried and crushed into molding powder which release air and solid emissions. Pellets are formed by drying and cutting, usually in a screw-extruder, and then are passed through a dust collector and an oversized screener. The wastes occur as air emission, liquid wastes, and solid residues. The liquid wastes result because oil and grease used as lubricants are released. Solid residues result from the oversize screening process. Air emissions are released from the extruders and the dust collectors. Sometimes the pellets are processed further in a fiber spinning process. Air, liquid, and solid emissions may occur.

Another characteristic of the polymerization processes is that monomers slowly polymerize in the pipelines, especially in the monomer recovery system pipelines. These lines must be cleaned out periodically, and the polymers are scrapped.

20.2 Production Process - Polyvinyl Chloride by Polymerization

Vinyl resins rank second in production to polyethylene. More emission data are available on the production of polyvinyl chloride (PVC) than polyethylene. Vinyl chloride monomer is one of the EPA's 129 priority pollutants; ethylene is not a priority pollutant. Therefore, the manufacturing process described in detail with emission points for this section will be the process for the manufacture of polyvinyl chloride by polymerization of vinyl chloride monomer: an addition reaction.

21.0 PYROLYSIS

Pyrolysis, also known as cracking, is the decomposition of chemical compounds by heat alone.

The organic chemicals that are manufactured by pyrolysis are listed in Table 21. A typical pyrolysis production process is presented in Figure 21.

Table 21. (Continued)

Product	Amount kkg	Feedstock	Other Required Processes
Propylene	6,440,359[1]	Propane Butane Naphtha Gas oil	None

Source: Herrick et al. 1979a.

[1] Source: USITC, Synthetic Organic Chemicals, 1979.
Assumes 100% of products were made by pyrolysis.

[2] Source: SRI 1981.
Assumes 80% of capacity is produced and also assumes the amount produced was by pyrolysis.

[3] Source: SRI 1981.
Does not give amounts produced, but lists producers.

21.1 Description of Discharges

Releases from a typical pyrolysis process occur in wastewater, as fugitive gaseous emissions, and in solid residues.

fugitive emissions	- occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains, and cooling towers (Wetherhold et al. 1981).
pyrolysis section	- combustion gases from a gas-fired furnace. - hydrocarbon and coke particulate emissions when decoking the furnace. - contaminated water from steam generation.
product cooling	- contaminated quench water or oil that comes in direct contact with the products in the quench towers. - contaminated cooling water from leaks in heat exchangers.
product purification	- product contaminants are removed by caustic scrubbers, oil scrubbers, gas scrubbers, or absorbers which will have liquid waste streams containing these contaminants. - gas scrubbers generally vent or flare pollutants to air.
separation of products and by-products	- strippers, fractionation columns; the undesired bottoms product will have to be disposed of or recycled.
cooling tower and boiler blowdown	- operation of the steam generation and cooling water systems produces the major portion of wastewater from pyrolysis units.

Specific releases are quantified in Versar (1982).

TABLE 22. REFORMING STEAM-WATER GAS PRODUCTS AND THEIR MANUFACTURE IN 1980

Products	Amount^a kkg	Feedstock	Other Required Processes
Methanol^b	1,276,000	Naphtha	None
Methanol^b		Natural Gas	None
Methanol^c	2,850,000	Naphtha	None
Methanol^c		Natural Gas	None
Methanol^c		Liquified Petroleum	None
Methanol^c		Naphtha	
Dimethyl Ether		Carbon dioxide	
Total	4,126.000		

Source: Herrick et al. 1980.

[a] Source: SRI 1981

These amounts are 80 percent of the capacities reported in SRI 1981. A density of 49.3 lb/ft^3 (0.792 g/cm^3) was assumed. The ratio of production by high pressure to that by low pressure was obtained from White 1980b.

[b] High pressure process.

[c] Low pressure process.

Distillation section	- vents on the distillation columns and flash tank will emit products and by-products. - a water waste stream will be removed and treated.

Specific releases for this process are quantified in Versar (1982).

23.0 SULFONATION AND SULFATION

Sulfonation is the process by which the sulfonic acid group ($\cdot SO_2OH$), the corresponding salt ($\cdot SO_2O-$), or the fulfonyl halide ($\cdot SO_2OX$) is attached to a carbon or a nitrogen atom. Sulfation involves the placement of an $\cdot OSO_2OH$ group on carbon when sulfating an alkene or of an $\cdot SO_2OH$ group on oxygen when sulfating an alconol or a phenol.

The principal organic chemicals manufactured by sulfonation and sulfation are listed in Table 23. Figure 23 is the flow diagram for the manufacture of methyl methacrylate.

23.1 Description of Discharges

Releases from a typical sulfonation or sulfation process occur in wastewater, as vent gases, and as fugitive gaseous emissions.

Fugitive	- occur from valves, flanges, pump seals, compressor seals, pressure relief valves, drains and cooling towers, and storage tanks.
Sulfonation/sulfation section	- neutralization crystals. - vent gases from columns and wastewater from columns.

Specific releases for this process are quantified in Versar (1982).

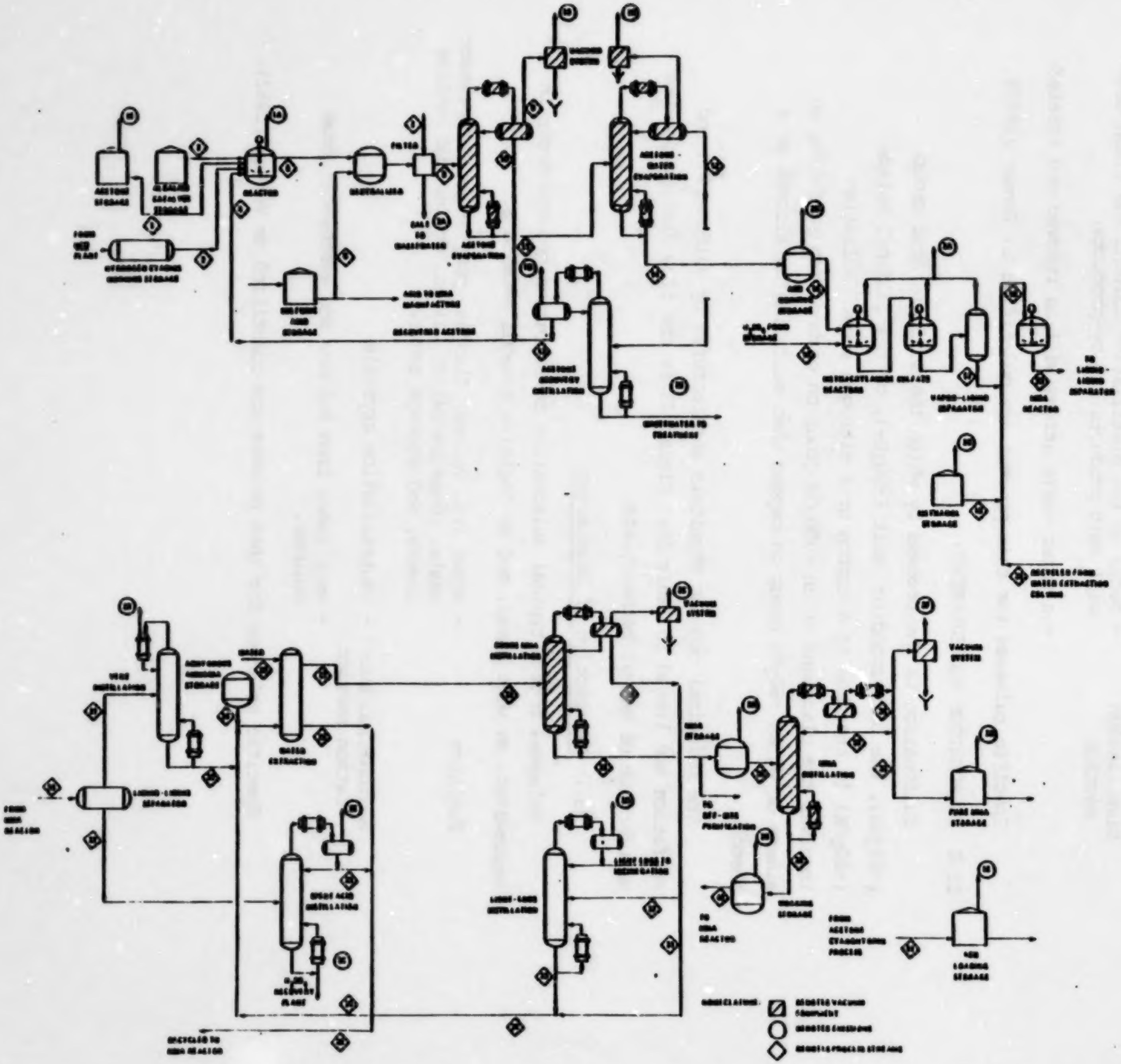

ACETONE STORAGE
REACTOR
NEUTRALIZER
FILTER
ACETONE EVAPORATION
VACUUM SYSTEM
ACETONE-WATER EVAPORATION
ACETONE RECOVERY DISTILLATION
WASTEWATER TO TREATMENT
RECOVERED ACETONE
METHACRYLAMIDE SULFATE REACTORS
VAPOR-LIQUID SEPARATOR
MMA REACTOR
TO LIQUID-LIQUID SEPARATOR
METHANOL STORAGE
VACUUM SYSTEM
LIQUID-LIQUID SEPARATOR
FROM MMA REACTOR
WATER
WATER EXTRACTION
CRUDE MMA DISTILLATION
LIGHT-ENDS DISTILLATION
SPENT ACID DISTILLATION
RECYCLED TO MMA REACTOR
MMA STORAGE
MMA DISTILLATION
PURE MMA STORAGE
TO MMA REACTOR
NOMENCLATURE:
DENOTES VACUUM COMPONENT
DENOTES EMISSIONS
DENOTES PROCESS STREAMS

Figure 23. Flow diagram for the manufacture of methyl methacrylate.

TABLE 24. SIC CODES APPLIED TO THE PLASTIC PRODUCTS INDUSTRY

SIC Code	Title
3021	Rubber and plastics footwear
3041	Rubber and plastics hose and belting
3079	Miscellaneous plastics products
3451	Screw machine products (produced on a job order basis
3479	Coating, engraving, and allied services not elsewhere classified
3728	Aircraft parts and auxiliary equipment
3963	Buttons
3944	Toys and amusement, sporting, and athletic goods
3714	Motor vehicle parts and accessories

TABLE 25. (Continued)

Process	Resin(s) Processed	Process Description
Compression molding	Thermosets	Compression molding is the most common method of molding thermoset plastics. The molding powder or pellets are placed in open mold cavities, and the face of the mold is pressed down. Pressure and heat are then applied for a specified amount of time for curing and shaping of the product. Mold heating is accomplished by steam, gas, oil, electronic coils, or electric cartridge element. The processes are usually fully automated. Automatic compression-molding presses perform all of the routine molding processes of thermosetting plastics: measuring the charge of the molding powder or preforms, preheating it, loading into cavities, closing the mold, opening it for breathing (gas expulsion), closing it for a predetermined curing period, opening it and ejecting the finished pieces, blowing the flash from the cavities and plungers, and repeating the cycle over again.
Transfer molding	Thermosets	Transfer molding is similar to compression molding, in that the thermoset plastics are cured in the mold under heat and pressure. The molding pellets or powder are first placed in a pressure chamber and heated to a plastic state by contact with the heated surface of the pressure chamber. The plastic then flows through a narrow passage, which may be heated, and is forced into a hot, closed molding cavity. High pressure and heat are applied to the filled cavity to set (cure) the formed plastic material. The finished article is ejected from the mold cavity and air-cooled.
Calendering	Thermoplastic*	Calendering is used to process thermoplastics into sheeting or film, and to apply a plastic coating to textiles or other supporting materials. The process involves passing the film or sheeting between a series of 3 or 4 large, heated revolving rollers, which squeeze the material between them into a sheet or film. Process cooled at 340°F.

TABLE 25. (Continued)

Process	Resin(s) Processed	Process Description
Laminating	Thermosets	High pressure and temperature are often used in lamination. The thermosetting plastics are used to bind the reinforcing materials that comprise the body of the finished product; the reinforcing materials may be cloth, paper, wood, or glass fibers and the products may be flat sheets, rods, or tubes. In producing flat sheets, impregnated sheets are stacked between 2 plates and subjected to high heat and pressure; the process cures the plastic and produces a single material. For producing tubing, resin-treated reinforcing sheets are wrapped, under tension and/or pressure around a heated rod, and subsequently cured in the oven. In producing formed shapes, the reinforcing material is cut into pieces, and fitted into the mold to cure under heat and pressure.
Rotational molding	Mainly thermoplastics; some thermosets	Intended primarily for manufacture of hollow objects, it involves the placement of a polymer into a warm mold, which is rotated in an oven about 2 axes. During heating if the polymer is powdered material, a porous skin is formed on the mold surface; this gradually melts as the cycle progresses to form a homogeneous layer. When molding a liquid, the material flows and coats the mold surface until it gels, at which time flow ceases. After cooling, the molds are opened for removal of the molded parts.
Reaction injection molding	Thermoplastics & thermosets	Also termed liquid injection molding, this process has been primarily for molding polyurethane elastomers or foams into products - solid integral skins and cellular cores. Two or more pressurized reactive streams are impinged together under pressure in a mixing chamber; the resultant mixture is injected, under low pressure, into the mold where the reaction begins and continues until the liquid mixture solidifies into the product.

2. Accidental flash contact.

3. Accidental dust contact during cutting or machining operations.

4. Inhalation of oxidation or pyrolysis products.

5. Inhalation of materials from fugitive leaks in processing equipment.

6. Inhalation of gases escaping from opening or closing the molds.

7. Inhalation of gases escaping from loading or unloading operations.

8. Inhalation of gases released during the cooling process.

9. Unexpected sudden release of pressure in pipelines containing chemicals.

10. Entry into reactors, where there may be high vapor concentrations.

The plastics processors are the mainstay of the industry. They turn the plastics materials into secondary products, e.g., film, sheet, rod, tube, etc., component parts,or finished end-products. Processors can be classified according to whether they are processing on a custom basis for end-users, "custom processors," or whether they represent captive (in-house) production facilities for manufacturers who use plastics parts in large volume, "captive processors." Plastics processors can also be classified, more specifically, according to the type of processing they employ (Frados 1977).

To assess the occupational exposure in the plastics processing industry, three factors must be considered. These are:

1. The plastic material itself, the modifying agent used and its toxicity.

2. The operating parameters of the processing techniques employed.

3. The degree of automation of the processes employed.

phenolics, a condensation-polymerization reaction occurs in the molds. This results in the formation of by-product gases, which must be vented during molding to prevent the formation of bubbles or distortions in the end products. Whereas transfer and injection molds have vents, compression molds are opened during curing to release these by-product gases (see Table 26). If the work area is not adequately vented, there exists a large potential for exposure to possibly noxious fumes during compression molding (Agranoff 1980-1981).

Operating parameters are important in assessing occupational exposure, because even relatively inert materials, when sufficiently heated in excess of the appropriate processing range, may pose a potential for hazard. For example, polyethylene, at sufficiently high temperatures, will pyrolyze, yielding materials which are irritating to the eyes and respiratory tract (Society of the Plastics Industry 1973). The following section further discusses exposure to noxious materials during plastics processing.

Possible Exposure to Noxious Fumes During Processing

Most plastics are normally processed within the temperature range of 140 - 340°C; within this range, especially at the upper end of the range and depending on the polymeric material and the fabrication process, fumes and gases are very often observed. The fumes can include carbon monoxide, formaldehyde, and acrolein, and are generally low in concentrations, except at the very top of the temperature range. These fumes are adequately removed by appropriate precautionary measures, such as vents.

While some of the fumes are produced or formed by pyrolysis, others are formed by oxidation. It is also possible that there may be a release of impurities, either from the plastic material, or from one or more of the additives. The fumes released will differ from one plastic to another, but almost all will release carbon monoxide in the temperature range of 140 - 340°C during

TABLE 26. (Continued)

Plastics Process	Exposure Potential
Extrusion	• If cooling is by air blasts, exposure to gases is possible. • Potential for exposure when the molding powder or pellets are conveyed from the hopper to the extruders (particulate emissions) or when the hot product is conveyed to the cooling area. • Potential for exposure to gases from leaks in the extruder.
Injection molding	• Potential for exposure to gases when molds are opened, especially thermosets. By-product gases from curing will be released. • Gases may escape through leaks in the heating chamber and molds and may pose a potential for exposure. • Particulate emissions may occur when the molding powder or pellets are added to the hopper.
Casting	• Requires controlled heating and thus operation is usually completely enclosed. • Casting of PVC film may involve exposure to solvent.
Coating	• During spraying, atomized plastic particles present hazards due to toxic and explosive characteristics of the materials; ventilation is required. • Amount of material lost during spraying operations is three times that actually deposited. High inhalation exposure potential).
Foam	• The potential for inhalation exposure to the gases released upon heating exists. • Exposure to gas during aging of product is possible.
Laminating	• Dermal contact with liquid varnishes or resins poses potential for exposure, especially when pressure is applied. • If work area is not properly ventilated, the potential for exposure to solvents released during curing exists.

processing. Aldehydes can also be released from certain polymeric materials. The concentrations of these fumes to which workers would be exposed, in the absence of proper ventilation, are dependent on workers' positions in relation to the source of the fumes, i.e., processing equipment (Edgerley 1981).

Edgerley (1981) reported that carbon monoxide evolved at temperatures from about 200°C and above, when 12 polymeric materials were tested. In his experiments, Edgerley was careful to point out that while the 'onset of CO' temperature is exceeded by the maximum recommended temperature in many cases, it does not mean that oxidative pyrolysis was taking place to any serious extent (see Tables 27 and 28). Evolution of formaldehyde from polyethylenes tested increased with temperature to a maximum at or above 280°C, whereas evolution of acrolein was significant above 140°C (see Table 29). Above this temperature, a rapid increase in the rate of evolation was reported.

Gases other than carbon monoxide, formaldehyde, and acrolein can also be released during plastics processing; benzene may evolve in the case of certain polymers containing aromatic ring structures. Table 30 presents information on the gases evolved from plastics manufacture, along with their concentrations and TLV.

Results of atmospheric sampling tests performed close to certain types of plastics processing equipment are presented in Table 31. Sampling devices were placed close to points where polymers emerged into the open air, and also in the operator's work area. The presence of carbon monoxide, acrolein, and formaldehyde was confirmed, especially at the high end of the processing temperature range at or near the point at which the polymer emerges into the air. As adequate ventilation was provided, the potential for exposure was diminished.

In addition to the evolution of gases during plastics processing, the exothermic nature of the oxidation of organic polymers to carbon monoxide poses the potential for problems in

TABLE 28. CARBON MONOXIDE EVOLUTION IN THE MELTING AND PROCESSING TEMPERATURE RANGE OF VARIOUS PLASTICS

Material	Tm (°C)	Tg (°C)	Compression Molding (°C)	Injection Molding (°C)	Extrusion (°C)	Onset of CO Evolution	CO can Reach 500 ppm (°C)
LD Polyethylene	110 - 130	90 - 105	140 - 220	205 - 290	220 - 310	200	375
HD Polyethylene	120 - 140		150 - 230	150 - 315	150 - 340	200	375
EVA (4% VA)	90		50 - 150	120 - 220	150 - 220	220	305
Polypropylene	176		170 - 235	205 - 290	220 - 310	200	290
PVC		75 - 105	140 - 220	165 - 195	150 - 210	240	450
Polystyrene		100	130 - 205	165 - 260	190 - 255	240	380
PMMA		90 - 105	150 - 220	165 - 260	205 - 260	280	never
Polycarbonate		150	150 - 325	250 - 345	230 - 290	330	410
PET	258			290 - 315	230 - 320	280	375
Nylon 6 6	265			270 - 325	270 - 330	200	355
ABS		88 - 120	165 - 235	195 - 275	200 - 235	310	420

The processing temperatures were obtained from the Modern Plastics Encyclopedia 1978.

Source: Edgerley 1981.

TABLE 30. EVOLUTION OF CERTAIN GASES FROM PLASTICS AT THE MAXIMUM RECOMMENDED PROCESSING TEMPERATURE

Polymer	Temperature (°C)	Gas	Concentration (ppm)	TLV (ppm)
Polyvinylchloride	205	Hydrogen chloride	120	5
		Benzene	2	10
Polycarbonate	345	Benzene	trace <1	10
PET	345	Benzene	trace <1	10
Nylon 6.6	325	Hydrogen cyanide		10
		Ammonia	~60	25
		Nitrous fumes	trace 0.5	25
Acrylonitrile/ Butadiene. Styrene (ABS)	275	Hydrogen cyanide	1	10
		Ammonia	5	25
		Nitrous fumes	trace <0.5	5
		Styrene	<50	100
Polystyrene	260	Benzene	trace <1	10
		Styrene	trace <50	100
EVA (4 percent VA)	220	Acetic acid	<5	10
		Vinyl acetate	<5	10
EVA (28 percent VA)	220	Acetic acid	25 ppm	10
		Vinyl acetate	<5	10

Source: Edgerley 1981.

occupational settings. This is because once the reaction has started, the rate can increase expontentially due to a rise in the temperature. Consequently, in situations where heat cannot be readily removed, polymer plastics caught on die-lips or on a hot knife will rise in temperature and will generate more gaseous oxidation products than might be expected (Edgerley 1981).

TABLE 32. DESCRIPTION OF PROCESSES EMPLOYED IN THE ASSEMBLY, FINISHING, AND DECORATION OF PLASTICS PARTS

Adhesive bonding	Most often the most efficient, economical, and durable method of plastics assembly. 1. Elastomeric adhesives used to assemble elastomers. Solvent-based, applied by spray or brush. Require ventilation to eliminate solvent hazards. 2. Thermoplastic resins used with other plastics. Solvent-based or applied to parts as melts at elevated temperatures. 3. Thermosetting resins are most versatile, durable, and environmentally resistant adhesives. Curing involves heat or mixture of two components. Single component, room-temperature curing systems are growing rapidly in use. Automated glue-guns or pressure time applicators. 4. Miscellaneous adhesive types are available as water-based systems. Methods 1. Brushing - labor-intensive. 2. Dipping - difficult with solvent cements. 3. Roll coating - efficient for uniform coating of areas. 4. Spraying - rapid method for large areas, also imparts preciseness to small areas. Requires venting and operator protection. 5. Stencil/screening - not suited to solvent-type adhesives. 6. Pressure - time applicators impart preciseness to small area application. Can be factored into automated production lines.
Electromagnetic bonding	Based on induction heating; magnetic materials develop heat loss when subjected to high frequency alternating current source. Equipment consists of induction generator, water-cooled copper work coils, fixturing, and electromagnetic material.
Friction joining	Heat for melting plastics materials is generated by friction. With parts held under pressure, one part is made to move relative to the other; sufficient thermal energy is generated to form a melt layer. One part has to be thermoplastic. Movement of the part can be rotational (spin welding) or rapid back-and-forth displacement of limited amplitude (vibrational welding).

TABLE 32. (Continued)

	Automatic 2. Rotary joining, stations provided for clamping, heating, joining, and cooling and unloading. Manual or automatic. 3. Groove joining, used to join flat sheets of plastic to the end of a plastic pipe. 4. Hot gas welding, uses gaseous heat source to melt the areas of plastics to be joined and a plastics welding rod.
Ultrasonic	Becoming preferred method for plastics assemble; parts are clamped or scanned under vibrating horn. Highly localized frictional heating results as plastic joint or horn interfaces, resulting in a thin layer of molten plastic, which subsequently solidifies upon cooling.
Decorating and Printing	
Dyeing and printing	Aqueous system and "disperse" class of textile dyes used. Dye bath is from 150 - 200°F. Parts are degreased, placed in dye bath, removed, rinsed, and dried. Exposure may occur by contact with dyes.
Electroplating	Chemical etchants used to bond the metal deposits on plastic surface. Preplating treatment involves application of a conductive coating, cleaning with acidic, alkaline, or even a neutral detergent. Etchants are usually strongly acidic, oxidizing solutions often containing high concentrations of chromium trioxide.
Embossing	Thermoplastic sheet is textured with a pattern imparted by an embossing roll pressing against a backup roll under controlled preheating and postcooling conditions. Process parameters involve 1) product compounding and related properties, 2) sheet thickness, 3) preheat temperature, 4) embossing roll design, and 5) postemboss cooling.
Flock coating	The system is a continuous web line incorporating letoff, knife overoll coaster, flock machine, vacuum blanket, curing oven, cooling station, vacuum brush, and rewind. Final procesing phase, curing and drying, involves temperatures from 275 to 325°F of plastisol adhesives.

TABLE 32. (Continued)

Vacuum metalizing	Metal or other material is deposited on plastic material. Aluminum is used to impart lustrous finish to objects. Vacuum metalizing chamber is the heart of the process. Four steps are involved; loading, base coating, vacuum coating, and top coating. Base coating seals pores and reduces outgassing. Outgassing increases with temperature rise and diminishing absolute pressure. Parts are baked in connection or infrared ovens.
Machining	Used in place of molding. Involves turning, drilling, end milling, face milling, power bank sawing, and tapping. Machining can also be performed with lasers.

Source: Agranoff 1980-1981.

DERESINING/DEASPHALTING

Propane solvent is used to deresin and/or deasphalt the cylinder stock. Asphalts occur as asphaltene crudes. Resins occur in parafin or low-alsphaltic cylinder stocks. The propane solvent is recovered and reused.

DEWAXING

Solvent dewaxing with MEK and toluene is the most common approach to dewax lube oils. MEK crystallizes the wax within the oil and toluene dissolves the oil. The wax is removed through solvent injection and chilling. Both wax solution and oil solution are distilled to remove, recover, and reuse the solvent. Dewaxing the wax distillate results in neutral stock (∿ SAE motor oil). Dewaxing the cylinder stock results in bright stock (∿ SAE 70 motor oil).

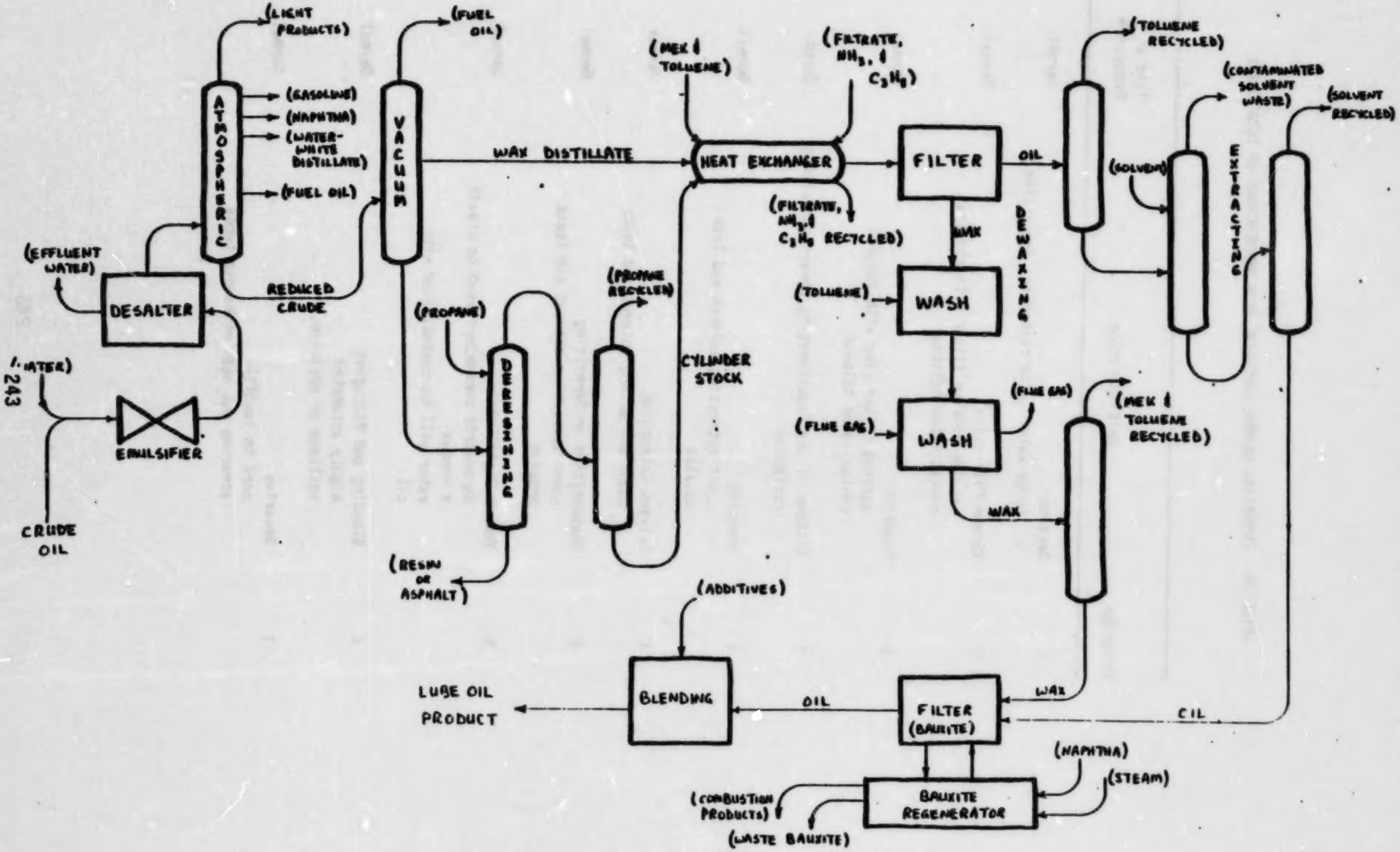
Dewaxing results in oil-free wax and wax-free oil.

SOLVENT EXTRACTION

Solvent extraction removes compounds that cause low viscosity indexes. Typically, chlorex, nitrobenzene, phenol, furfural, or benzene are used with SO_2. The solvent is removed, reclaimed, and reused from the improved oil (raffinate) and the extract.

FILTRATION

Bauxite is the typical filter medium used to remove undesirable asphalts and resins not previously removed in the deasphalting/deresining step. Filtration is also used as a simple finishing step. The bauxite is washed with naphtha, steamed, and then regenerated by burning of the adsorbed material and reused. Some refiners use hydrogen and a catalyst (hydrocracking) instead of bauxite filtration to improve the quantity and quality of the lubricating oil.



CRUDE OIL
(WATER)
EMULSIFIER
DESALTER
(EFFLUENT WATER)
ATMOSPHERIC
(LIGHT PRODUCTS)
(GASOLINE)
(NAPHTHA)
(WATER-WHITE DISTILLATE)
(FUEL OIL)
REDUCED CRUDE
VACUUM
(FUEL OIL)
WAX DISTILLATE
(PROPANE)
DERESINING
(RESIN OR ASPHALT)
(PROPANE RECYCLED)
CYLINDER STOCK
(MEK & TOLUENE)
HEAT EXCHANGER
(FILTRATE, NH₃, & C₃H₈)
(FILTRATE, NH₃, & C₃H₈ RECYCLED)
FILTER
OIL
WAX
DEWAXING
(TOLUENE)
WASH
(FLUE GAS)
WASH
(FLUE GAS)
WAX
(MEK & TOLUENE RECYCLED)
(TOLUENE RECYCLED)
(SOLVENT)
EXTRACTING
(CONTAMINATED SOLVENT WASTE)
(SOLVENT RECYCLED)
WAX
OIL
FILTER (BAUXITE)
BAUXITE REGENERATOR
(NAPHTHA)
(STEAM)
(COMBUSTION PRODUCTS)
(WASTE BAUXITE)
OIL
(ADDITIVES)
BLENDING
LUBE OIL PRODUCT

Figure 24. Manufacture of Lubricants from Petroleum

TABLE 34. POTENTIAL DERMAL EXPOSURE FROM MANUFACTURE OF LUBRICANTS

Priority	Unit Operation	Type of Exposure*
1	Desalter large water waste containing impurities	Dermal
2	Vacuum Filtration washing bauxite filter with naphtha contaminated naphtha	Dermal
3	Dewaxing washing filter cake with toluene contaminated toluene	Dermal
3	Bottoms of any fractionating towers containing residuals	Dermal
4	Dewaxing spent extracting solvent and leaks toluene	Dermal
4	Solvent Extraction spent extracting solvent and leaks	Dermal
4	Deasphalting or Deresining spent extracting solvent and leaks propane	Dermal
5	Vacuum Distillation barometric condensers used to create a vacuum water will be contaminated with oil	Dermal
6	Blending and Packaging highly automated spillage of additives	Dermal
1	Dewaxing sent to landfill scraping out heat exchanger tubes	Dermal

APPENDIX A-4

General Manufacturing Processes

Introduction

Processes inherent to all manufacturing industries can only be very generally characterized. The wide variety of processes and equipment in use necessitates a generic approach to evaluation of these exposure sources. When using these definitions to evaluate specific processes, try to make common-sense associations. For example, exposure via dyeing may be likened to wet mixing and open-surface tanks.

Processes

Abrasive blasting. Abrasive blasting equipment may be automatic or it may be manually operated. Either type may use sand, steel shot, or artificial abrasives. The dust levels of workroom air should be examined to make certain that the operators are not overexposed.

Abrasive machining. An abrasive machining operation is characterized by the removal of material from a workpiece by the cutting action of abrasive particles contained in or on a machine tool. The workpiece material is removed in the form of small particles and, whenever the operation is performed dry, these particles are projected into the air in the vicinity of the operation.

Assembly operations. Improper positioning of equipment and handling of work parts may present ergonomic hazards due to repeated awkward motion resulting in excessive stresses.

Bagging and handling of dry materials. The bagging of powdered materials (such as plastic resins, paint pigments, pesticides, cement, and the like) is generally accompanied by the generation of

Ceramic coating. Ceramic coating may present the hazard of airborne dispersion of toxic pigments plus hazards of heat stress from the furnaces and hot ware.

Fabric and paper coating. The coating and impregnating of fabric and paper with plastic or rubber solutions may involve evaporation into the workroom air of large quantities of solvents.

Crushing and grinding. Size reduction refers to the mechanical reduction in size of solid particulate material. Two of the principal methods of achieving size reduction are crushing and grinding, but the terms are not synonymous. Crushing generally refers to a relatively slow compressive action on individual pieces of coarse material ranging in size from several feet to under one inch. Grinding is performed on finer pieces and involves an attrition or rubbing action as well as interaction between individual pieces of material. Pulverizing and disintegrating are terms related to grinding. The former applies to an operation producing a fine powder; the latter indicates the breakdown of relatively weak interparticulate bonds, such as those present in caked powders. Dry grinding operations should be examined for airborne dust, noise, and ergonomic hazards.

Grinding operations. Grinding, crushing, or comminuting of any material may present the hazard of contamination of workroom air due to the dust from the material being processed or from the grinding wheel.

Dry mixing. Mixing of dry material may present a dust hazard and should take place in completely enclosed mixers whenever air sampling indicates excessive amounts of airborne dust are present.

Open-surface tanks. Open-surface tanks are utilized by industry for numerous purposes. Among their applications can be included the common operations of degreasing, electroplating, metal stripping, fur and leather finishing, dyeing, and pickling. An open-surface tank operation is defined as "any operation involving the immersion of materials in liquids, which are contained in pots, tanks, vats, or similar containers." Excluded from consideration in this definition, however, are certain similar operations such as surface-coating operations and operations involving molten metals for which different engineering control requirements exist.

Paint spraying. Spray painting operations should be examined for the possibility of hazards from inhalation and skin contact with toxic and irritating solvents and inhalation of toxic pigments. The solvent vapor evaporating from the sprayed surface may also be a source of hazard, because ventilation may be provided only for the paint spray booth.

Plating. Electroplating processes involve risk of skin contact with strong chemicals and may present a respiratory hazard if mist or gases from the plating solutions are dispersed into the workroom air.

Pouring stations for liquids. Wherever "volatile" substances are poured from a spout into a container, some release of contaminants can be expected. In the paint and other coatings industries, solvents may be released when the contents of mills or mixers are poured into portable change cans. While ladles and change cans can be covered while being moved through a workplace, they must of necessity be open at the points where they are filled or discharged.

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APPENDIX B
INFORMATION RESOURCE MATRIX

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Foreword

This appendix has been specifically developed to support the conduct of occupational exposure assessments. It is not intended to be all-inclusive or state-of-the-art in its coverage. It is intended to be a preliminary guide to information sources. No control was possible over the accuracy and/or timeliness of the 47 resources contained within this compilation beyond what is provided in the individual resource excerpts and abstracts. An attempt was made to weed out obviously out-of-date or irrelevant information sources. For the purpose of this product, an information resource has been defined loosely as any source of information and/or data and includes but is not limited to:

- data bases
- bibliographic retrieval systems
- non-bibliographic retrieval systems
- standard reference manuals
- encyclopedias
- journals and books

The major sources used to compile these two volumes include:

- USEPA, EPA Environmental Data Base and Model Index-Draft Directory, May 1981. Office of Planning and Management, Information Clearing House, EPA.
- USDC, A Directory of Federal Statistical Data Files, March 1981. Office of Federal Statistical Policy and Standards, U.S. Dept. of Commerce. PB 81-133175.
- USEPA, Environmental Information Systems Directory, January 1976. Office of Planning and Management, EPA. PB 251 170.
- USDHHS, Environmental Health - A Plan for Collecting and Coordinating Statistical and Epidemiologic Data, DHHS Publication No. (PHS) 80-1248. Office of Health Research, Statistics, and Technology; National Center for Health Statistics, Public Health Service; Dept. of Health and Human Services.

How to Use this Matrix

The matrix is arranged with the Information Resources on the vertical axis and the descriptive parameters on the horizontal axix. The numbers of the Information Resources correspond to the individually tabbed excerpts and abstracts in the accompanying support package.

A bullet (•) indicates that information on that particular descriptive parameter can be found in that particular Information Resource. An open circle (o) indicates that information on that particular descriptive parameter might possibly be found in that particular Information Resource or that information might be extrapolated from other information in that resource.

Neither the EPA nor the Contractor assumes any responsibility for the information contained within the individual excerpts or abstracts of the 47 information resources. Sole responsibility lies with each contact for each individual resource. Use of trade names does not warrant endorsement by either the EPA or the Contractor.

NUM.	INFORMATION RESOURCE	MATERIALS BALANCE								DEM.	MONITORING			MODELING			STATUS				
		PRIMARY PRODUCTION	SECOND. PROD/FAB.	TERTIARY FABRICATION	NON-PROD/FAB USES	IMPORTS & EXPORTS	TRANSPORTATION	WAREHOUSING ETC.	EMISSION FACTORS	DEMOGRAPHIC FACTORS	INDOOR ENVIRON.	OUTDOOR ENVIRON.	BIOLOGICAL	INDOOR ENVIRON.	OUTDOOR ENVIRON.	BIOLOGICAL	OPERATIONAL	TERMINATED	PROPOSED	LONG TERM	SHORT TERM
1	ANN. OCC. INJ. & ILL. SURVEY								○	●			●				●			●	
2	BIBLIOGRAPHIC RETR. SERVICE	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●			●	
3	CHEM. & PROC. TECH. ENCYCLO.	○	○		○			○	○								●				
4	CHEMICAL ECONOMICS HANDBOOK	●	○	○	●	●		○									●				
5	CHEMICAL ENGINEERING	○	○	○	○	○	○	○	○								●				
6	CHEM. ENG. & NEWS	○	○	○	○	○	○	○	○								●				
7	CHEM. IN COMMERCE INFO. SYSTEM	●	●	●	●	●											●				●
8	CHEMICAL PLANT DATA	●	●	○	○	○											●				
9	CHEM. SUBSTANCES INFO. NETWORK	●	●	●	●			○	●	●	○	○	●			○	○		●	○	
10	CHEMICAL WEEK	○	○	○	○	○	○	○	○								●				
11	CROSS SECT. INDUST. STUDIES									●			●				●			●	
12	DIRECTORY OF CHEMICAL PROD.	●	●	○	○	○											●				
13	ECONOMIC INFORMATION SYSTEMS	●	●	●	●	○				●							●			●	

NUM.	INFORMATION RESOURCE	MATERIALS BALANCE								DEM.	MONITORING			MODELING			STATUS				
		PRIMARY PRODUCTION	SECOND. PROD/FAB.	TERTIARY FABRICATION	NON-PROD/FAB USES	IMPORTS & EXPORTS	TRANSPORTATION	WAREHOUSING ETC.	EMISSION FACTORS	DEMOGRAPHIC FACTORS	INDOOR ENVIRON.	OUTDOOR ENVIRON.	BIOLOGICAL	INDOOR ENVIRON.	OUTDOOR ENVIRON.	BIOLOGICAL	OPERATIONAL	TERMINATED	PROPOSED	LONG TERM	SHORT TERM
27	KIRK-OTHMER ENCY. CHEM. TECH.	○	○	○	●			○	○								●				
28	LOCKHEED DIALOG INFO. RET. SER.	●	○	○	●	●	●	○	○	●	○	○	○	○	○	○	●			●	
29	MULTIMEDIA ASSESS. INORG CHEM.	●	●		●				●				●					●		●	
30	NATL. ELEC. INJURY SURV. SYS.									●			●				●				●
31	NIH/EPA CHEM. INFO. SYSTEM				●			○	●			●	●				●			●	
32	NATL. OCC. HAZARD SURVEY									●	●		●					●			●
33	OCC. HAZARD EXPOSURE REGISTRY									●			●				●				●
34	OCC. REL. DISEASE CASE REGIS.									●			●				●				●
35	ORGANIC CHEM. PROD. DATA BASE	●	●		●				●								●				●
36	OUT. STUD. WORK. SEL. IND. OCC.									●			●				●			●	
37	PEST. ANAL. RET. & CONTROL SYS.	●	○		●												●			●	
38	PEST. DOCUMENT MANAG. SYSTEM	●	○		●								●				●				●
39	PEST. INCIDENT MONITOR. SYSTEM				●								●				●			●	

Table 1. Profile of data collection systems that measure population health status

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
Annual Occupational Injuries and Illness Survey	BLS	To provide data on work-related disease and injury.	Acute disease and acute injury by cause, with or without lost work days. Fact of death.	Industry. Establishment size.	Morbidity Record Survey. Probability sample of employers under OSHA recordkeeping, stratified by industry and establishment size	Since 1972, ongoing surveys of nearly all private sector industries across the United States.	Tape. Publication.	Incidence of illness and injury by type of case per plant-hour worked.

An Introduction to BRS

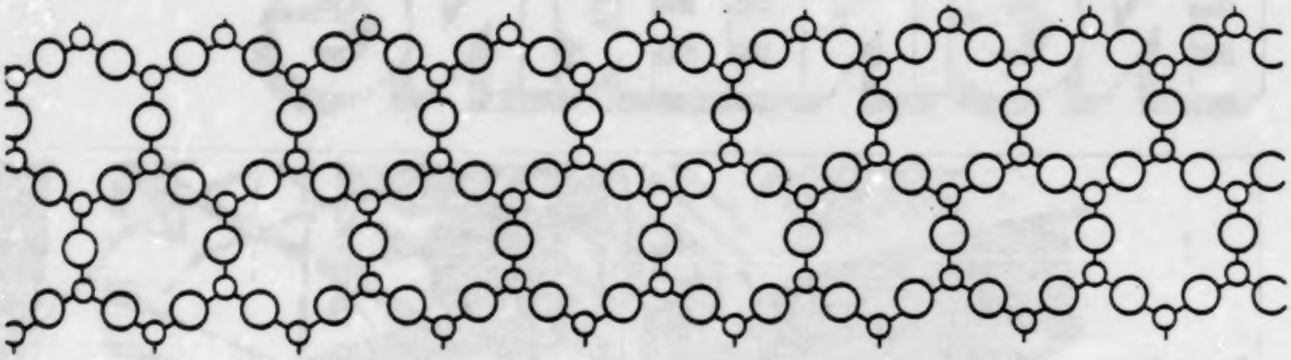
BRS was established in 1976 to provide innovative and cost-effective online information retrieval services and technology to a national user community.

By introducing lower connect hour rates, group membership plans and subscription access, BRS quickly became the system of choice for online users in academic, government, and special libraries throughout the United States, Canada, and Europe.

In addition to the BRS Online Search Service for commercially available databases, BRS also offers a comprehensive private database service, a sophisticated SDI service, online searching of card catalogs, and lease or purchase plans for its highly specialized retrieval software programs.

BRS is the only online vendor that provides this full range of online products and services, extending its technology to many diverse applications within the library and information community.

Let BRS help you meet *all* your information needs!



chemical and process technology encyclopedia

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São Paulo Singapore Toronto
Montreal Mexico Sydney
Panama New Delhi

CHEMICAL ENGINEERING

A McGRAW-HILL PUBLICATION
AUGUST 27, 1979

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Curbing fugitive emissions

DRAFT

D7301700904

Chemicals in Commerce Information System

Acronym: CICIS
Media sampled to generate data: No specific media
Type of data collection/monitoring: chemical manufacturing and production data
Data base status: Operational/ongoing

ABSTRACT: The Toxic Substances Control Act (TSCA) provides EPA with authority to regulate commercial chemical substances, which pose unreasonable risk to man and the environment. CICIS supports this effort. Information maintained are chemical, plant, and production volumes. It contains chemicals manufactured or imported in the U.S., what chemicals are manufactured or imported at a given site, where plants are located, and their names. There are data for about 55,000 chemicals in CICIS, including the approximately 700 in the clearinghouse.

Non-pollutant parameters include: Chemical data
Location
Manufacturer
Production levels

Ongoing study time period is 01/01/77 to 12/30/77
Termination of data collection: Occurred 12/30/73

Frequency of data collection: one time only
TSCA allows EPA to collect additional information, as required, which may serve to update the data base.

Total estimated number of observations is 48000 substances.
Estimated annual increase of observations is unknown.

Data base includes: Summary or aggregate observations

Total number of stations or sources covered is 8000 sites.
Number currently contributing data is 0.

Geographic coverage of data base: National
Facility identifiers include: Plant facility name
Plant location
Street address
Dun and Bradstreet number
Program identifier
Pollutant identification data have: CAS registry number codes

Limitations: The CICIS On-line User's Guide should be consulted prior to accessing the information. Quality assurance questions are not applicable.

Edit procedures used and documented.

Data collected by: Contractor - Chemical Abstracts Service

CPD

Scope:

Chemical Plant Data (CPD) is designed to provide worldwide information on chemical plants producing, or planning to produce, any of more than 100 basic chemicals. Currently, 114 cnemicals, or in some cases classes of chemicals, are covered. The information available through this service is based upon material collected from a wide range of sources published in many languages, and includes technical literature, company information, annual reports, etc. In addition, companies are approached to verify the information thus provided.

Subject coverage includes:

- 114 chemical commodities
- Producing plant listings (worldwide)
- Plant capacities, start-up date
- Production/Sales/Statistical summaries
- Producer/Process/Feedstock

Access:

Currently, Chemical Plant Data is disseminated primarily in hard copy form. Online computer retrieval of this information is, however, in the planning stages. For further information contact:

The Sales Department
Chemical Data Services
Dorset House, Stamford Street
London, SE1 9LU, ENGLAND

Cost:

Not available.

Sample Search/Output:

Not applicable.

Wind direction
Wind velocity
Presence of data elements varies by resource
(data base)

Ongoing study time period is 01/01/70 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: frequency of collection, sampling, updating dependent on rate established by each resource in the network.

Total estimated number of observations is 2.5 million.
Estimated annual increase of observations is 15-20 million.

Data base includes: Raw data/observations
Summary or aggregate observations
Reference data/citations
varies by resource/data base

Total number of stations or sources covered is 8-10 resources.
Number currently contributing data is 3.

Geographic coverage of data base: International
National

Location identifiers of station/source for each record are: State
County
Congressional district
SMSA
City
Town/township
Street address
Coordinates
Project identifier
varies by
resource/data base

Facility identifiers include: Plant facility name
Plant location
Parent corporation name
Parent corporation location
Street address
SIC code
Dun and Bradstreet number
SCC
NPDES
Program identifier
varies by resource/data base

Pollutant identification data have: CAS registry number codes

Limitations: The prototype, operational '81, includes NLM (Medlars Chemline, etc.) CIS and CICIS, 5-7 additional resources will be added in calendar '81. Each resource on the network has front end caveats which speak to differences in periods

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Form of available reports and outputs: Publications overview documents, technical user documents, CSIN Directory
Unpublished reports
Printouts on request
Microfilm
Machine-readable raw data
On-line computer
Outputs available vary by resource/data base.

Current regular users of data base: 10-50 offices

Users: EPA headquarter offices - Office of Pesticides and Toxic Substances Office of Toxic Integration
EPA regional offices
EPA laboratories
Other federal agencies
States
Industry, academia, and other nations.

Confidentiality: Limits on access within EPA and outside agency for some data

Primary physical location of data: Contractor
EPA lab
Regional office
NCC/UNIVAC
NCC/IBM
Headquarters office
State agency
Other federal agency
Varies by resource/data base.

Form of data storage: Magnetic tape
Magnetic disc
Microfich/film
Original form (hardcopy, readings)
Varies by resource/data base

Data access: EPA software MIDSD system number: 7500000901
data identified, located & accessed through the CSIN front end.

Contact - Subject matter: Dr. Sidney Siegel (202)755-8040
Contact - Computer-related: Dr. Sidney Siegel (202)755-8040
Contact - responsible EPA Office: Office of CSIN Administration (202)755-8040

Charge for non-EPA use: yes
Frequency of master file up-date: varies by resource/data base.

Related EPA systems: Chemical Information System (CIS), Chemicals in Commerce Information System (CICIS)
Related EPA data bases: Storage and Retrieval of Water Quality and Related Data (STORET), User Prompted Graphic Data Evaluation System (UPGRADE), Health and Environmental Effects Data Analysis System (HEEDA)
Related non-EPA data bases: National Library of Medicine - bibliographic files (NLM), Toxicology Data Management System (TDMS), Chemical Regulations and Guidelines System (CRGS), PROPHET (National Institutes of Health)

Table 3. Profile of data collection systems that test specific interrelationships—Con.

(Agency designations by acronym are listed in figure 1)

Name of program system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
Cross Sectional Industrial Studies	NIOSH	To understand relationship between type of industry and illness of reproductive system.	Physical symptoms.	Occupational history. Current levels of selected pollutants proximal to worker.	Cohort studies. Exposed and control groups are selected. Interviews with all employees and in some cases medical examinations are conducted.	Series of industrywide studies, beginning in 1971.	Special reports.	Relative risk statistics. Morbidity rates. Average exposure to selected pollutants.

ECONOMIC INFORMATION SYSTEMS, Inc.

SHARE-OF-MARKET AND SHIPMENTS REPORTS

on U.S. manufacturing industries

The story behind EIS reports

The immediate source of EIS reports is the EIS Business Data Base. This Data Base is a comprehensive store of information on the business sector of the U.S. economy. It contains detailed records on the top 300,000 business establishments with 20 or more employees that account for 85% of business sales—their names, addresses, phone numbers, types of business, number of employees and parent company ownership.

In addition, the EIS Data Base can interface with a unique body of information—EIS "input-output" ratios. These ratios enable us to calculate the volume of sales and purchases of virtually all products and services bought and sold by U.S. business establishments. A library of computer programs enables us to manipulate the information in the Data Base to produce selective marketing reports on many aspects of the economy.

The accuracy and currency of the EIS Data Base derives from its structure, source material and maintenance/update procedures.

Founded in 1968, the Data Base was constructed to parallel U.S. Census Bureau records on business activity. It incorporates all available information on business establishments and firms published in the classified sections of U.S. telephone directories, state and industrial directories, annual reports and SEC 10K statements. All this data is reconciled each year with the corresponding "control" totals published by the U.S. Census Bureau for industries and regions.

Quarterly updating of the Data Base utilizes an accumulation of new information from published sources, plus feedback from EIS clients on new establishments, changes in plant size and other field-based findings.

Many types of reports can be furnished from the EIS Data Base. Among them are:

Shipments and Share-of-Market Reports on Manufacturing Industries. These reports analyze any manufacturing industry in terms of key producers and ownership structure.

Market Share Reports on "Non-Manufacturing" Industries. These reports, concentrating on commercial/service industries, identify and rank by market share all major companies and their subsidiaries.

Sales Structure Reports analyze individual companies in terms of sales, market share and diversity of operations.

Market Potential Reports identify establishments and firms that use any industrial product or service, with estimates of the amount each one uses.

Market Penetration Analyses utilize your own customer lists to build a profile of your company's share-of-market in each industry in which it operates.

Market Projection Reports forecast the growth trends of business markets for any of your company's products or services.

For detailed information on these reports, and the full scope of EIS services, contact Economic Information Systems, Inc. by phone or mail.

ECONOMIC INFORMATION SYSTEMS, Inc.

LINE OF BUSINESS REPORTS

on major diversified U.S. companies

The story behind EIS reports

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ECONOMIC INFORMATION SYSTEMS, Inc.

MARKET SHARES REPORTS

on mining, construction, transportation, utilities, trade and service industries

The story behind EIS reports

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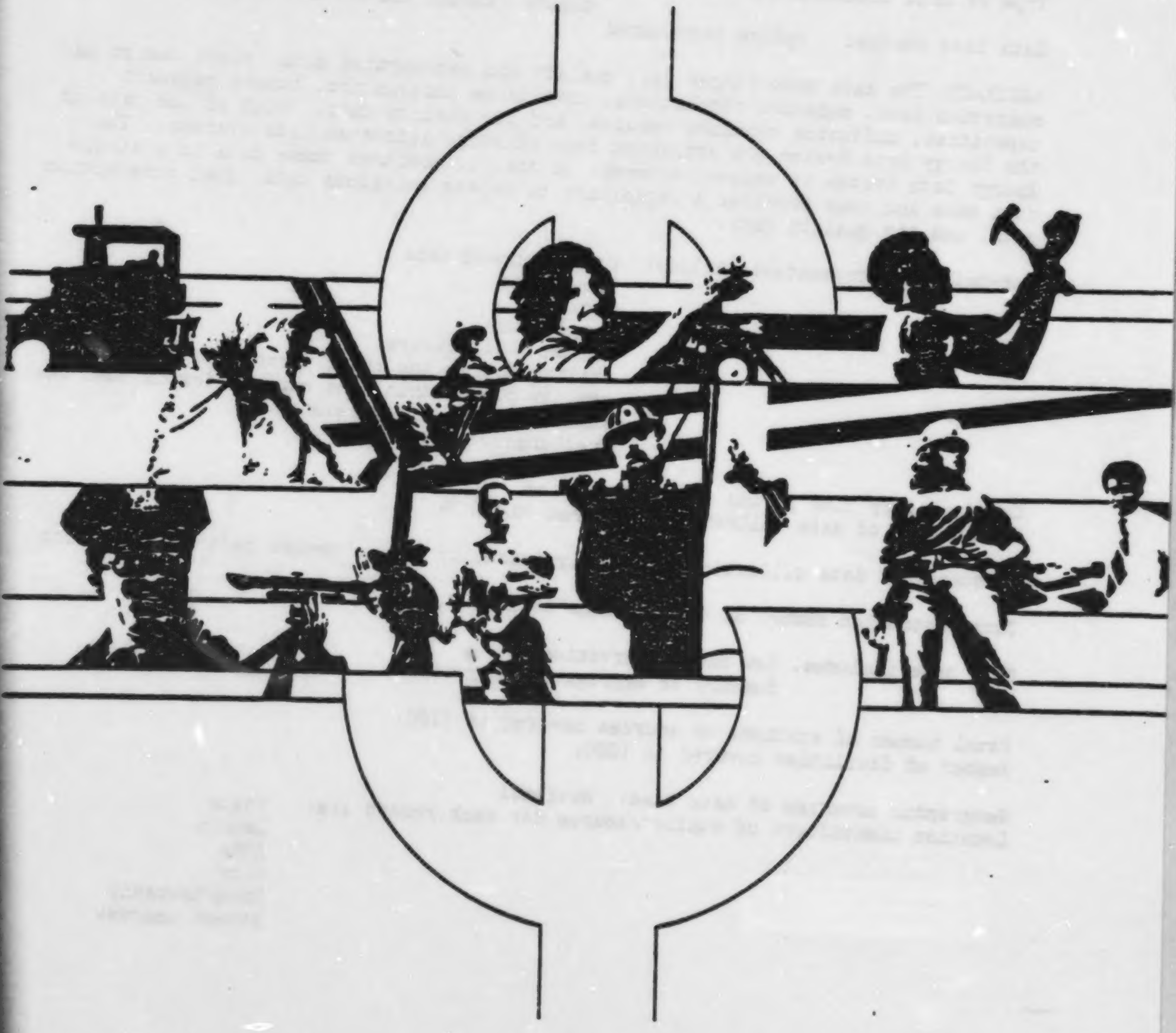
Employment and Earnings
October 1981

U.S. Department of Labor
Bureau of Labor Statistics



DRAFT

D4505000902

Energy Data System

Acronym: EDS
Media sampled to generate data: Other No specific media: Data related to fossil fuel combustion taken from Department of Energy forms on the utility sector.
Type of data collection/monitoring: Point source data collection Utility power plants (annual and monthly reports)
Data base status: Update terminated

ABSTRACT: The data base stores fuel quality and consumption data, plant design and operation data, emission regulations, compliance information, future megawatt capacities, diffusion modeling results, and air quality data. Much of the data in the Energy Data System are extracted from existing automated data systems. The Energy Data System is unique, however, in that it combines these data in a single data base and thus provides a capability to relate emissions data, fuel consumption data, and air quality data.

Non-pollutant parameters include:
- Cost/economic data
- Flow rates
- Location
- Temperature
- Volume/mass measures
- utility boiler and stack parameters
- utility plant annual and monthly fossil fuel use
- individual fuel procurements
- fuel characteristics

Ongoing study time period is 01/01/69 to 12/30/78
Termination of data collection: Occurred 10/30/79

Frequency of data collection: monthly, annually and as needed before termination

Total estimated number of observations is 250000.

Data base includes:
- Raw data/observations
- Summary or aggregate observations

Total number of stations or sources covered is 1200.
Number of facilities covered is 1200.

Geographic coverage of data base: National
Location identifiers of station/source for each record are:
- State
- County
- SMSA
- City
- Town/township
- Street address

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DATA SOURCE D: ECDIN
ENVIRONMENTAL CHEMICALS DATA AND INFORMATION NETWORK

Review Date: February, 1981

D.1 BACKGROUND

The Environmental Chemicals Data and Information Network (ECDIN) project was established to provide a data bank of environmental chemicals for European communities.

ECDIN was begun in 1973 and is still in pilot phase. When the system is fully operational, it will provide information on chemical products of environmental significance. Eventually, the system is expected to include 20,000 - 30,000 chemicals.

The finished ECDIN system will cover chemical identity, physical-chemical properties, chemical production, and health and environmental effects.

D.2 STATUS

For the pilot phase, 4,000 chemicals were selected. From this group, a smaller list of priority compounds were chosen for data collection. The identification category is completed for most compounds. About one half of the entered compounds include toxicity data, and more detailed information is present for an even smaller number of compounds.

Whenever possible, ECDIN will answer questions directed to the system regarding chemicals and their effects. Users can gain direct access to the data bank by contacting ECDIN. At this point, there are no charges for answering queries.

D.3 SCIENTIFIC PARAMETERS

It is planned that ECDIN will have 11 categories of data, some of which are further divided into more specific scientific parameters. The 11 scientific parameters can be roughly divided into eight general groups:

- Chemical Identifiers
- Physical-Chemical Properties
- Analytical Methods
- Manufacturing Information
- Environmental Effects
- Environmental Fate
- Health Effects
- Legal Implications

Use and Disposal

Most of the data in this field are unstructured and, by necessity, the category covers a wide variety of data types.

- **Environmental Fate**

Dispersion and Transformation in the Environment

This topic deals with the behavior of the chemical in the environment. It provides insight into where the compound might accumulate and what its by-products are.

- **Environmental Effects**

Effects of the Chemical on the Environment

This category is concerned with environmental effects data. More specific types of data are contained in this category. They are as follows:

- Effects on ecosystems
- Effects on inanimate material
- Effects on plants

- **Health Effects**

Effects of the Chemical on Health

This section includes all human and environmental toxicity data. The more specific categories are as follows:

- Human toxicity
- Animal toxicity data
- Terrestrial toxicity
- Aquatic toxicity
- Microorganism toxicity
- Effects on in-vitro systems
- Effects on reproduction (including teratogenicity)
- Carcinogenicity
- Mutagenicity
- Allergic and immunological reactions
- Odor threshold values

Occupational Safety and Health

The safety and health recommendations and hazards for the workplace and employees are included in this category.

Chemical Substances Regulated by the Occupational Safety and Health Administration

The following is a listing of those chemical substances regulated by OSHA. Physical agents are not included in this listing. Full documentation of OSHA regulations concerning the listed substances can be found in 29 CFR 1910.

Acetaldehyde
Acetic acid
Acetic anhydride
Acetone
Acetonitrile
Acetylene dichloride, see 1, 2-Dichloroethylene
Acetylene tetrabromide
Acrolein
Acrylamide—Skin
Aldrin—Skin
Allyl alcohol—Skin
Allyl chloride
C Allylglycidyl ether (AGE)
Allyl propyl disulfide
2-Aminoethanol, see Ethanolamine
2-Aminopyridine
Ammonia
Ammonium sulfamate (Ammate)
n-Amyl acetate
sec-Amyl acetate
Aniline—Skin
Anisidine (o, p-isomers)—Skin
Antimony and compounds (as Sb)
ANTU (alpha naphthyl thiourea)
Arsenic organic compounds (as As)
Arsine
Azinphos-methyl—Skin
Barium (soluble compounds)
p-Benzoquinone, see Quinone
Benzoyl peroxide
Benzyl chloride
Biphenyl, see Diphenyl
Boron oxide
C Boron trifluoride
Bromine
Bromoform—Skin
Butadiene (1, 3-butadiene)
Butanethiol, see Butyl mercaptan
2-Butanone
2-Butoxy ethanol (Butyl Cellosolve)—Skin
Butyl acetate (n-butyl acetate)
sec-Butyl acetate
tert-Butyl acetate
Butyl alcohol
sec-Butyl alcohol
tert-Butyl alcohol
C Butylamine—Skin
C tert-Butyl chromate (as CrO_3)—Skin
n-Butyl glycidyl ether (BGE)
Butyl mercaptan
p-tert-Butyltoluene
Calcium oxide
Camphor
Carbaryl (Sevin®)
Carbon black
Carbon dioxide
Carbon monoxide
Chlordane—Skin
Chlorinated camphene—Skin
Chlorinated diphenyl oxide
C Chlorine
Chlorine dioxide
C Chlorine trifluoride
C Chloroacetaldehyde
a-Chloroacetophenone (phenacylchloride)
Chlorobenzene (monochlorobenzene)
o-Chlorobenzylidene malononitrile (OCBM)
Chlorobromomethane
2-Chloro-1,3-butadiene, see Chloroprene
Chlorodiphenyl (42 percent Chlorine)—Skin
Chlorodiphenyl (54 percent Chlorine)—Skin
1-Chloro, 2,3-epoxypropane, see Epichlorhydrin
2-Chloroethanol, see Ethylene chlorohydrin
Chloroethylene, see Vinyl chloride
C Chloroform (trichloromethane)
1-Chloro-1-nitropropane
Chloropicrin
Chloroprene (2-chloro-1,3- butadiene)—Skin
Chromium, sol. chromic, chromous salts as Cr
Metal and insol. salts
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene
Cobalt, metal fume and dust
Copper fume
Dusts and Mists
Cotton dust (raw)
Crag® herbicide
Cresol (all isomers)—Skin
Crotonaldehyde
Cumene—Skin
Cyanide (as CN)—Skin
Cyclohexane
Cyclohexanol
Cyclohexanone
Cyclohexene
Cyclopentadiene
2,4-D
DDT—Skin
DDVP—Skin
Decaborane—Skin
Demeton®—Skin
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)
1,2-diaminoethane, see Ethylenediamine
Diazomethane
Diborane
Dibutyl phosphate
Dibutylphthalate
C o-Dichlorobenzene
p-Dichlorobenzene
Dichlorodifluoromethane
1,3-Dichloro-5,5-dimethyl . hydantoin
1,1-Dichloroethane
1,2-Dichloroethylene
C Dichloroethyl ether—Skin
Dichloromethane, see Methylenechloride
Dichloromonofluoromethane
C 1,1-Dichloro-1-nitroethane
1,2-Dichloropropane, see Propylenedichloride
Dichlorotetrafluoroethane
Dieldrin—Skin
Diethylamine
Diethylamino ethanol—Skin
Diethylether, see Ethyl ether
Difluorodibromomethane
C Diglycidyl ether (DGE)
Dihydroxybenzene, see Hydroquinone
Diisobutyl ketone
Diisopropylamine—Skin
Dimethoxymethane, see Methylal
Dimethyl acetamide—Skin
Dimethylamine
Dimethylaminobenzene, see Xylidene
Dimethylaniline (N-dimethyl- aniline)—Skin
Dimethylbenzene, see Xylene
Dimethyl 1,2-dibromo-2,2-dichlorethyl phosphate, (Dibrom)
Dimethylformamide—Skin
2,6-Dimethylheptanone, see Diisobutyl ketone
1,1-Dimethylhydrazine—Skin
Dimethylphthalate
Dimethylsulfate—Skin
Dinitrobenzene (all isomers)—Skin
Dinitro-o-cresol—Skin
Dinitrotoluene—Skin
Dioxane (Diethylene dioxide)—Skin
Diphenyl
Diphenylmethane diisocyanate
(see Methylene bisphenyl isocyanate (MDI)
Dipropylene glycol methyl ether—Skin
Di-sec, octyl phthalate (Di-2- ethylhexylphthalate)
Endrin—Skin
Epichlorhydrin—Skin
EPN—Skin
1,2-Epoxypropane, see Propylenoxide
2,3-Epoxy-1-propanol, see Glycidol
Ethanethiol, see Ethylmercaptan
Ethanolamine
2-Ethoxyethanol—Skin
2-Ethoxyethylacetate (Cellosolve acetate)—Skin
Ethyl acetate
Ethyl acrylate—Skin
Ethyl alcohol (ethanol)
Ethylamine
Ethyl sec-amyl ketone (5- methyl-3-heptanone)
Ethyl benzene
Ethyl bromide
Ethyl butyl ketone (3- Heptanone)
Ethyl chloride
Ethyl ether
Ethyl formate
C Ethyl mercaptan
Ethyl silicate
Ethylene chlorohydrin—Skin
Ethylenediamine
C Ethylene glycol dinitrate and/or Nitroglycerin—Skin
Ethylene glycol monomethyl ether acetate, see Methyl cellosolve acetate
Ethylene imine—Skin
Ethylene oxide
Ethylidine chloride, see 1,1- Dichloroethane
N-Ethylmorpholine—Skin
Ferbam
Ferrovanadium dust
Fluoride (as F)
Fluorine
Fluorotrichloromethane
Formic acid
Furfural—Skin
Furfuryl alcohol
Glycidol (2,3-Epoxy-1- propanol)
Glycol monoethyl ether, see 2-Ethoxyethanol
Guthion®, see Azinphosmethyl
Helium
Heptachlor—Skin
Heptane (n-heptane)
Hexachloroethane—Skin
Hexachloronaphthalene—Skin
Hexane (n-hexane)
2-Hexanone
Hexone (Methyl isobutyl ketone)
sec-Hexyl acetate
Hydrazine—Skin
Hydrogen bromide
C Hydrogen chloride
Hydrogen cyanide—Skin
Hydrogen peroxide (90%)
Hydrogen selenide
Hydroquinone
C Iodine
Iron oxide fume
Isoamyl acetate
Isoamyl alcohol
Isobutyl acetate
Isobutyl alcohol
Isophorone
Isopropyl acetate
Isopropyl alcohol
Isopropylamine
Isopropylether
Isopropyl glycidyl ether (IGE)
Ketene
Lindane—Skin
Lithium hydride
L.P.G. (liquified petroleum gas)
Magnesium oxide fume
Malathion—Skin
Maleic anhydride
C Manganese
Mesityl oxide
Methanethiol, see Methyl mercaptan
Methoxychlor
2-Methoxyethanol, see Methyl cellosolve
Methyl acetate
Methyl acetylene (propyne)

Methyl acetylene-propadiene mixture (MAPP)
Methyl acrylate—Skin
Methylal (dimethoxymethane)
Methyl alcohol (methanol)
Methylamine
Methyl amyl alcohol, see Methyl isobutyl carbinol
Methyl (n-amyl) ketone (2- Heptanone)
C Methyl bromide—Skin
Methyl butyl ketone, see 2- Hexanone
Methyl cellosolve—Skin
Methyl cellosolve acetate—Skin
Methyl chloroform
Methylcyclohexane
Methylcyclohexanol
o-Methylcyclohexanone—Skin
Methyl ethyl ketone (MEK), see 2-Butanone
Methyl formate
Methyl iodide—Skin
Methyl isobutyl carbinol—Skin
Methyl isobutyl ketone, see Hexone
Methyl isocyanate—Skin
C Methyl mercaptan
Methyl methacrylate
Methyl propyl ketone, see 2- Pentanone
C# Methyl styrene
C Methylene bisphenyl isocyanate (MDI)
Molybdenum:
  Soluble compounds
  Insoluble compounds
Monomethyl aniline—Skin
C Monomethyl hydrazine— Skin
Morpholine—Skin
Naphtha (coaltar)
Naphthalene
Nickel carbonyl
Nickel, metal and soluble cmpds, as Ni
Nicotine—Skin
Nitric acid
Nitric oxide
p-Nitroaniline—Skin
Nitrobenzene—Skin
p-Nitrochlorobenzene—Skin
Nitroethane
C Nitrogen dioxide
Nitrogen trifluoride
C Nitroglycerin—Skin
Nitromethane
1-Nitropropane
2-Nitropropane
Nitrotoluene—Skin
Nitrotrichloromethane, see Chloropicrin
Octachloronaphthalene—Skin
Octane
Oil mist, mineral
Osmium tetroxide
Oxalic acid
Oxygen difluoride
Ozone
Paraquat—Skin
Parathion—Skin

Pentaborane
Pentachloronaphthalene—Skin
Pentachlorophenol—Skin
Pentane
2-Pentanone
Perchloromethyl mercaptan
Perchloryl fluoride
Petroleum distillates (naphtha)
Phenol—Skin
p-Phenylene diamine—Skin
Phenyl ether (vapor)
Phenyl ether-biphenyl mixture (vapor)
Phenylethylene, see Styrene
Phenyl glycidyl ether (PGE)
Phenylhydrazine—Skin
Phosdrin (Mevinphos®)— Skin
Phosgene (carbonyl chloride)
Phosphine
Phosphoric acid
Phosphorus (yellow)
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus trichloride
Phthalic anhydride
Picric acid—Skin
Pival® (2-Pivalyl-1,3- indandione)
Platinum (Soluble salts) as Pt
Propane
n-Propyl acetate
Propyl alcohol
n-Propyl nitrate
Propylene dichloride
Propylene imine—Skin
Propylene oxide
Propyne, see Methylacetylene
Pyrethrum
Pyridine
Quinone
Rhodium, Metal fume and dusts, as Rh
Soluble salts
Ronnel
Rotenone (commercial)
Selenium compounds (as Se)
Selenium hexafluoride
Silver, metal and soluble compounds
Sodium fluoroacetate (1080)—Skin
Sodium hydroxide
Stibine
Stoddard solvent
Strychnine
Sulfur dioxide
Sulfur hexafluoride
Sulfuric acid
Sulfur monochloride
Sulfur pentafluoride
Sulfuryl fluoride
Systox, see Demeton®
2,4,5T
Tantalum
TEDP—Skin
Tellurium
Tellurium hexafluoride
TEPP—Skin
C Terphenyls
1,1,1,2-Tetrachloro-2,2-difluoroethane

1,1,2,2-Tetrachloro-1,2-difluoroethane
1,1,2,2-Tetrachloroethane—Skin
Tetrachloromethane, see Carbon tetrachloride
Tetrachloronaphthalene—Skin
Tetraethyl lead (as Pb)—Skin
Tetrahydrofuran
Tetramethyl lead (as Pb)— Skin
Tetramethyl succinonitrile— Skin
Tetranitromethane
Tetryl (2,4,6-trinitrophenyl- methylnitramine)—Skin
Thallium (soluble compounds)—Skin as Tl
Thiram
Tin (inorganic cmpds, except oxides
Tin (organic cmpds)
C Toluene-2,4-diisocyanate
o-Toluidine—Skin
Toxaphene, see Chlorinated camphene
Tributyl phosphate
1,1,1-Trichloroethane, see Methyl chloroform
1,1,2-Trichloroethane—Skin
Titanium dioxide
Trichloromethane, see Chloroform
Trichloronaphthalene—Skin
1,2,3-Trichloropropane
1,1,2-Trichloro 1,2,2-trifluoroethane
Triethylamine
Trifluoromonobromomethane
2,4,6-Trinitrophenol, see Picric acid
2,4,6-Trinitrophenylmethyl- nitramine, see Tetryl
Trinitrotoluene—Skin
Triorthocresyl phosphate
Triphenyl phosphate
Turpentine
Uranium (soluble compounds)
Uranium (insoluble compounds)
C Vanadium:
  V_2O_5 dust
  V_2O_5 fume
Vinyl benzene, see Styrene
Vinylcyanide, see Acrylonitrile
Vinyl toluene
Warfarin
Xylene (xylol)
Xylidine—Skin
Yttrium
Zinc chloride fume
Zinc oxide fume
Zirconium compounds (as Zr)

Benzene (Z37.40-1969)
Beryllium and beryllium compounds (Z37.29-1970)
Cadmium fume (Z37.5-1970)
Cadmium dust (Z37.5-1970)
Carbon disulfide (Z37.3-1968)
Carbon tetrachloride (Z37.17-1967).
Chromic acid and chromates (Z37.7-1971).
Ethylene dibromide (Z37.31-1970).
Ethylene dichloride (Z37.21-1969).
Fluoride as dust (Z37.28-1969)
Formaldehyde (Z37.16-1967)
Hydrogen fluoride (Z37.28-1969).
Hydrogen sulfide (Z37.2-1966)
Mercury (Z37.8-1971)
Methyl chloride (Z37.18-1969)
Methylene chloride (Z37.23-1969)
Organo (alkyl) mercury (Z37.30-1969)
Styrene (Z37.15-1969)
Tetrachloroethylene (Z37.22-1967)
Toluene (Z37.12-1967)
Trichloroethylene (Z37.19-1967).

4-Nitrobiphenyl
Alpha-naphthylamine
Methyl chloromethyl ether
3,3'-Dichlorobenzidine
Bis-chloromethyl ether
Beta-naphthylamine
Benzidine
4-Aminodiphenyl
Beta-propiolactone
2-Acetylaminofluorine
4-Dimethylaminoazobenzene
Dimethylaminobenzene
N-nitrosodimethylamine
Vinyl chloride
Coke oven emissions
Inorganic arsenic
Lead
1,2-Dibromo-3-chloropropane
Acrylonitrile

Epidemiological Studies Program System (ESPS) EISD #10209

- **Purpose:**

The ESPS aids research in the health effects of pesticide products by providing a comprehensive data base on health statistics for persons exposed to various pesticides.

- **Annual Cost:**

Computer	*Personnel*	*Contract Support*
$32,000	$25,000	$100,000

- **Primary Users:**

The twelve Epidemiological Study Project Groups, who are sponsored under this Program, use the data files to make health effects studies.

- **Description:**

This Program has taken over and expanded the Pesticide Community Studies Data System. This Program funds studies of a regional and national scope in such areas as, acute pesticide poisoning, pesticide usage surveys, and chronic effects of pesticide exposure. These study groups use a variety of techniques, such as health examinations, sampling and hospital records in order to develop and maintain a number of data bases. The average master file has 3,000 to 5,000 records with a large number of individual entries. Many of the records are medical histories updated over a period of time.

- **Operation:**

The Health Effects Branch of the Office of Pesticides Program has begun to exercise control over this data systems operation. Tapes containing the data from these individual projects are being delivered to the Branch for their data manipulation. This data is being used to review the findings of the field studies and to develop new statistical analyses and correlations. New software standards and data management techniques are being developed to better coordinate the work of the 12 individual projects.

- **Responsibility:**

System Sponsor: August Vandermer

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D3404000002

Establishment Registration Support System

Acronym: ERSS
Media sampled to generate data: pesticide production data
Type of data collection/monitoring: production information for pesticide products.
Data base status: Operational/ongoing

ABSTRACT: A centralized data base is used to support inspection planning and case preparation for pesticide enforcers by maintaining a nationwide file identifying all pesticide producing establishments and their types and amounts of annual production. Data covers pesticide products as defined by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), identified by product registration numbers. No chemical ingredient data is included.

Non-pollutant parameters include: Compliance data
Industry
Location
Production levels

Ongoing study time period is 01/01/75 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: annually

Total estimated number of observations is 120000.
Estimated annual increase of observations is 20000.

Data base includes: production volumes reported by producing establishments.

Total number of stations or sources covered is 8000.
Number currently contributing data is 8000.
Number of facilities covered is 8000.

Geographic coverage of data base: International, include foreign product imports to U.S.
Location identifiers of station/source for each record are: State
County
City
Street address
EPA Establishment Number

Facility identifiers include: Plant facility name
Plant location
Parent corporation name
Parent corporation location
Street address
EPA Establishment Number
Pollutant identification data have: pesticide registration number codes

Data collection and analysis procedures: Sampling plan documented
Collection method documented
Lab audit: Data not based on lab analysis.
Precision and accuracy estimates are not available
No known edit procedures exist.

Data collected by: Self reporting
Data analyzed by: data not analyzed

Compliance or enforcement is the primary purpose for data collection.
Program evaluation is the secondary purpose for data collection.
Statutory authorization is P L 95-396, Section 7 (Federal Insecticide, Fungicide and Rodenticide Act-FIFRA)
OMB form number: 158-R-0109
Form of available reports and outputs: Printouts on request
Machine-readable raw data
Current regular users of data base: 300
Users: EPA headquarter offices - Pesticides and Toxic Substances Enforcement Div., OPP, SPRD, BFSD.
EPA regional offices
Other federal agencies, NIH, U.S. Congress
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: NCC/IBM
Form of data storage: Magnetic tape
Data access: EPA software ERSS MIDSD system number: 3404000002
EPA hardware IBM 370/168

Contact - Subject matter: Carol Buckingham (202) 755-2647
Contact - Computer-related: Jean Malachowski (202) 683-0885
Contact - responsible EPA Office: John Martin (202) 755-1075

Charge for non-EPA use: yes
Frequency of master file up-date: Weekly

Related EPA systems: Pesticides Enforcement Management System.

Person completing form: Tim Shaw/John Martin
Office: EPA/(OE)/(OGE)/(PTSED)/
Address: Viar and Company 114 N. Columbus St. Alexandria, VA 22314
Phone: (703) 683-0885

Handbook of Labor Statistics

U.S. Department of Labor
Bureau of Labor Statistics
December 1980

Bulletin 2070

3 1283 00015 1949

DRAFT

D3103000903

Hazardous Waste Site Tracking System

Acronym: STS
Media sampled to generate data: No specific media: Inventory of hazardous waste sites with gross amounts of chemicals found at site
Type of data collection/monitoring: No monitoring data collection
Data base status: Operational/ongoing

ABSTRACT: The data base contains an inventory of potential hazardous waste sites both active and inactive, on-site of industrial facilities and off-site. Major functions supported include: inventory and identification, assessment, site inspection, hazards, hydrological analysis, and remedial and enforcement actions necessary.

Non-pollutant parameters include:
- Compliance data
- Cost/economic data
- Funding data
- Inspection data
- Location
- Physical data
- Political subdivisions
- Population demographics
- Population density
- Site description
- Hazards
- Waste state
- Waste characteristics
- Remedial actions

Ongoing study time period is 08/01/79 to 12/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: As events (e.g. inspections) are done

Total estimated number of observations is 20821.
Estimated annual increase of observations is 10000.

Data base includes: Raw data/observations

Total number of stations or sources covered is 3000.

Geographic coverage of data base: National
Location identifiers of station/source for each record are:
- State
- County
- City
- Street address
- Coordinates
- Latitude/Longitude Coordinates

Facility identifiers include: Plant facility name

Plant location
Parent corporation name
Street address
SIC code
Dun and Bradstreet number
NPDES

Lab analysis based on EPA-approved or accepted methods.
Lab audit: Data not based on lab analysis.
Precision and accuracy estimates are not available
Edit procedures used but undocumented.

Data collected by: State agency - Every state environmental protection agency
Regional office - Every Regional Office
Contractor - Various contractors
Data analyzed by: Regional office - Every Regional Surveillance and Analysis Division
Contractor lab - Various laboratories
Data base does not identify specific laboratory performing analysis.

Compliance or enforcement is the primary purpose for data collection.
Remedial action is the secondary purpose for data collection.
Program evaluation is the third purpose for data collection.
No statutory requirement: Data collection requirement is to aid in EPA tracking of hazardous waste sites
Form of available reports and outputs: Printouts on request
Current regular users of data base: 15 offices
EPA headquarter offices - Hazardous Waste Task Force; SUPERFUND; Office of Solid Waste; Office of Enforcement
EPA regional offices
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: NCC/IBM
Form of data storage: Magnetic disc
Data access: EPA software Site Tracking System
EPA hardware IBM 370

Contact - Subject matter: Margie Russell (202)426-7810
Contact - Computer-related: Bruce Rothrock (202)426-7240
Contact - responsible EPA Office: Hazardous Waste Task Force (202)426-7810

Charge for non-EPA use: no
Frequency of master file up-date: Weekly

Person completing form: Bruce Rothrock
Office: Office of Enforcement
Address: 401 M St. SW Washington, DC 20460
Phone: (202)426-7240

Pollutants included in data base:
acetaldehyde 75-07-0
acetic acid 64-19-7

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D7301700901

Health and Environmental Effects Data Analysis System

Acronym: HEEDA
Media sampled to generate data: toxicological end effects; structure-activity relationship modeling
Type of data collection/monitoring: literature and other agency health effects evaluation
Data base status: Funded for development Projected operational date:09/00/81

ABSTRACT: This system is a mechanism for testing and evaluating various chemical structure/activity relationship models to compare chemicals of known effects to chemicals of similar structure with well-documented effects. It is the Office of Toxic Substances repository for known toxicological and environmental effects of chemicals. The data base contains evaluated health and environmental effects data obtained from, inter alia, the GENETOX Program and the U.S. Fish and Wildlife Service. It is still under development and will be operational with a limited amount of data early in 1981.

Non-pollutant parameters include:
- Biological data
- Chemical data
- Health effects
- Physical data
- mathematical models for structure/activity correlation

Ongoing study time period is 01/01/30 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: as needed
file building/as funded

Total estimated number of observations is 455.
Estimated annual increase of observations is 800.

Data base includes: evaluated data generated by expert groups

Total number of stations or sources covered is 6.
Number currently contributing data is 5.
Number of facilities covered is 0.

Geographic coverage of data base: International
Facility identifiers include: Not applicable
Pollutant identification data have: CAS registry number codes

Limitations: Concentrations/levels of a chemical in a particular media are not included in this data base. Toxicity and physical-chemical data are included. Limits are proposed on access within EPA and outside agency for some data.

Data collection and analysis procedures: Sampling plan documented
Lab analysis not based on EPA-approved or accepted methods.

Precision and accuracy estimates exist but are not included in data base. Edits on existing Health and Environmental Effects Data Analysis (HEEDA) data. Edit procedures for new data may rely on contributor editing. Some evaluation to be done in-house.

Data collected by: Federal Agencies
industry
published literature
Data analyzed by: Contractor - University of Pennsylvania (cooperative agreement) - original HEEDA
EPA headquarters - Assessment Division and Management Support Division/Office of Toxic Substances
Data base does not identify specific laboratory performing analysis.

Risk assessment is the primary purpose for data collection.
Development of regulations or standards is the secondary purpose for data collection.
Statutory authorization is P L 94-469, Section 10 (Toxic Substances Control Act 15 2609)
Form of available reports and outputs: Unpublished reports format to be established
Printouts on request
On-line computer
Current regular users of data base: unknown
Users: EPA headquarter offices - Office of Toxic Substances
EPA regional offices
Other federal agencies
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: Contractor
Form of data storage: Magnetic disc
Data access: EPA software MIDSD system number: 7500000904
University of Pennsylvania IBM-will be moved to the Office of Toxic Substances December 20, 1980

Contact - Subject matter: Charles Auer (202) 426-9819
Contact - Computer-related: Tony Jover (202) 426-4697
Contact - responsible EPA Office: Paula Miles (202) 426-2447

Charge for non-EPA use: no outside use/access permitted
Frequency of master file up-date: system in transition

Person completing form: Paula Miles
Office: EPA/(OPTS)/(OTS)/(MSD)
Address: 401 M St. SW, Washington, DC
Phone: (202) 426-2447

Pollutants included in data base:
phenobarbital 50-06-6
mitomycin c 50-07-7
oestriol 50-27-1
oestradiol-17beta 50-28-2
d-lysergic acid diethylamide 50-37-3

Table 4. Profile of data collection systems that record environmental inspections—Con.

(Agency designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
Health Effects Evaluation Data Base	NIOSH	To summarize information obtained from hazard evaluations (HE) requested by employees or employers under the Occupational Safety and Health Act.	Symptoms and medical test results from workers examined during the HE.	Location and name of establishment, Standard Industrial Classification (SIC), hazards, occupations observed, results of environmental samples taken.	Inspection by industrial hygienists and occupational health physician specialists.	Nationwide, 1977-78. A total of 260 HE's are in this file.	Special request reports. Publications.	For internal use.

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D9055000903

Industrial Process Evaluations

Acronym: None
Media sampled to generate data: Effluents industrial
Runoff limited
in plant chemical process
Type of data collection/monitoring: Point source data collection pulp and paper plants, chemical industry, and herbicide and pesticide manufacturers
Data base status: Operational/ongoing

ABSTRACT: Evaluation of specific industries and industrial processes regarding the formation of toxicants by (1) National Pollutant Discharge Elimination System (NPDES) permit or Clean Water Act, Section 308 request to industry or (2) EPA contractor. Toxicants beyond the 129 Consent Decree Priority Pollutants are covered. Initial work is dry lab paper study of industrial process followed by chemical and/or biomonitoring testing by facility. Most of the data (90%) supplied by industry.

Non-pollutant parameters include:
Biological data
Chemical data
Concentration measures
Discharge points
Disposal
Geographic subdivision
Industry
Location
Production levels
Test/analysis method
Treatment devices

Ongoing study time period is 01/01/79 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: as needed

Total estimated number of observations is 4000.
Estimated annual increase of observations is 600-800.

Data base includes: Raw data/observations

Total number of stations or sources covered is 200.
Number currently contributing data is 90.
Number of facilities covered is 60.

Geographic coverage of data base: Selected federal region Region V
Location identifiers of station/source for each record are:
State
County
City
Town/township

DRAFT

Street address

Facility identifiers include: Plant facility name
Plant location
Parent corporation name
Parent corporation location
Street address
SIC code
NPDES

Pollutant identification data are: Uncoded

Limitations: Evaluation for toxicants only (sometimes conventional also). Quality Assurance varies by facility.

Data collection and analysis procedures: documented in quality assurance project plan
Lab analysis based on EPA-approved or accepted methods.
Lab audit is satisfactory for part of the data base.
Precision and accuracy estimates partially exist for the data base.
No known edit procedures exist.

Data collected by: Self reporting
Regional office - Surveillance and Analysis Division
Contractor - Dr. Patterson and Associates
Data analyzed by: Self reporting
Regional office - Surveillance and Analysis Division
Contractor lab - through Surveillance and Analysis Division
Data base identifies specific laboratory performing analysis.

Development of regulations or standards is the primary purpose for data collection.
Statutory authorization is P L 90-500 as amended, Section 308 (Clean Water Act-CWA)
Form of available reports and outputs: Unpublished reports Individual undistributed reports
Current regular users of data base: 40
Users: EPA headquarter offices - Effluent Guidelines Division
EPA regional offices
States
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: Regional office
Form of data storage: Original form (hardcopy, readings)
Data access: Manually

Contact - Subject matter: Glenn D. Pratt/Jon Barney (312) 353-2098
Contact - responsible EPA Office: Glenn D. Pratt/Jon Barney (312) 353-2098

Charge for non-EPA use: no
Frequency of master file up-date: as completed

Person completing form: Glenn Pratt
Office: EPA/Region V/Enforcement Division
Address: 230 S. Dearborn Chicago, Ill 60604
Phone: (312)353-2098

Yankelovich / Part 3:

Toward an ethic of commitment

Savin gambles on a strategy for growth

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Time for decisions on HAZARDOUS WASTE

PAGE 50

DATA SOURCE C: IRPTC
INTERNATIONAL REGISTER OF POTENTIALLY TOXIC CHEMICALS

Review Date: January, 1981

C.1 BACKGROUND

Development of the International Register of Potentially Toxic Chemicals (IRPTC) was begun in 1977, and is under the auspices of the United Nations Environment Program (UNEP). The project is still in the planning stages.

The IRPTC plan provides for much detail in reporting of physical-chemical properties and effects upon health and the environment.

C.2 STATUS

Currently, IRPTC is coordinating and incorporating data and instructions to develop the system. A total of 17 major categories of data are in the register, and these include information on the chemical, its manufacture, its health effects and its environmental effects. IRPTC is not currently available as a data base, either manually or in computer form, although information on some sixty compounds used to test the proposed data contents and organization are available in published form.

C.3 SCIENTIFIC PARAMETERS

IRPTC has 17 categories of data. Each consists of several scientific parameters. These 17 categories can be roughly divided into nine broad classifications:

- Chemical Identifiers
- Physical-Chemical Properties
- Manufacturing Information
- Environmental Effects
- Health Effects
- Environmental Fate
- Analytical Methods
- Removal
- Legal Implications

Each of these categories is explained in further detail with examples to illustrate the format.

o **Chemical Identifiers**

This section includes the following information:

- Chemical name
- Accession number (IRPTC NU)
- CAS number (CAS NU)
- molecular formula (MOLFM)
- molecular weight (MOLWT)
- structural formula (STRFM)
- Wiswesser Line Notation (WLN)
- definition (DEF)
- synonyms (SYN)

Examples of the chemical fields are given in Figure E.C.1 for the compound Acrylonitrile.

o **Physical-Chemical Properties**

This topic concerns the following information:

- melting point (MP)
- flash point (FP)
- density (DEN)
- boiling point (BP)
- flammable limits (FL)
- relative vapor density (RVDEN)
- vapor pressure (VP)
- adsorption coefficient (ADS)
- partition coefficient (PC)
- water solubility (AQSOL)
- additives (ADD)
- impurities (IMPUR)

Figure E.C.1 shows a typical entry for the chemical Acrylonitrile.

o **Manufacturing Information**

This section deals with the following aspects of chemical production and use.

Production/Consumption covers information relating to:

- geographic area
- quantity
- year
- reference

A typical entry is shown in Figure E.C.2.

Production processes include information pertaining to the:

- process
- impurities
- reference

A typical entry appears in Figure E.C.2.

The Use category includes such information as:

- use
- geographic area
- quantity

Figure E.C.2 shows a typical entry.

- o **Environmental Effects**

The environmental effects category incorporates information on a substance's effect upon the environment.

The pathways into the environment are described by information such as:

- pathway and receiving medium
- geographic area
- quantity
- time unit
- reference

A typical entry appears in Figure E.C.3.

Environmental concentration (residue) data include:

- medium
- geographic area
- concentration
- analytical method
- date of sampling
- reference

A typical entry is shown in Figure E.C.3.

- o **Health Effects**

The health effects field is very broad in its coverage, and includes a variety of data items:

Bioconcentration is the experimental determination that a higher concentration of a given substance is detected within an organism than in the surrounding (experimental) environment. The scientific parameters given include:

- test conditions
- water concentration
- organism
- bioconcentration factor and time
- calculation basis
- reference

An example of a typical entry appears in Figure E.C.4.

The clearance time for aquatic organisms refers to the amount of time it takes for an organism to rid (depurate) itself of a substance after being placed in clean water. The information supplied includes:

- test conditions
- organism
- quantity cleared
- reference

An example of a typical entry is given in Figure E.C.4.

The mammalian metabolites section includes the following scientific parameters:

- organism
- metabolites
- reference

A typical entry appears in Figure E.C.5.

The mammalian toxicity array shows the toxic effects associated with a chemical substance in relation to the amount of exposure. The scientific parameters include:

- exposure concentration/dose
- exposure period
- route
- organism
- effect
- reference

A typical entry appears in Figure E.C.5.

Carcinogenicity data include:

- evaluation
- reference

Also entered as part of this category are experimental results including:

- organism
- route
- exposure concentration/dose
- exposure period
- effect
- reference

Figure E.C.6. shows these types of entries.

Mutagenicity data cover the following experimental results:

- organism
- route
- exposure concentration/dose
- exposure period
- test results
- reference

When a mutagenicity entry involves a microorganism or cell culture, the scientific parameters entered include:

- test system or organism
- test results
- reference

Typical entries of both these types are shown in Figures E.C.7.

Neurotoxicity and behavior studies determine if a substance affects nerve tissues or behavior performance. The scientific parameters included are as follows:

- organism
- route
- exposure concentration/dose
- exposure period
- effect
- reference

An example of this type of entry appears in Figure E.C.8.

Potentiation studies determine if a chemical's toxic effects are increased if combined with widely used drugs and other chemicals. The scientific parameters provided include:

- organism
- chemical or drug
- reference

An example appears in Figure E.C.8.

Primary irritation is characterized by the following entries:

- organism
- route
- effect
- reference

Figure E.C.9 shows a typical entry.

Reproduction data are entered as follows:

- organism
- route
- exposure concentration/dose
- exposure period
- effect
- reference

A typical entry is shown in Figure E.C.9.

Sensitization data are entered as follows:

- organism
- route
- effect
- reference

A typical entry appears in Figure E.C.10.

The scientific parameters on teratogenicity appear in the following format:

- organism
- route
- exposure concentration/dose
- exposure data
- effect
- reference

A typical entry appears in Figure E.C.10.

Aquatic and terrestrial toxicity are included to provide information on the environmental toxicity of a substance. Each entry includes the following scientific parameters:

- organism or ecosystem
- exposure concentration/dose

- exposure period
- route of exposure (when applicable)
- effect
- reference

Typical entries for each of these fields appear in Figure E.C.11.

- **Environmental Fate**

The environmental fate field includes a variety of topics.

Biodegradation data are presented in the format:

- source of microorganisms
- test conditions
- analytical technique and quantity
- products and quantity produced
- reference

A typical entry is shown in Figure E.C.12.

The environmental fate data concern the transformation and transport of a chemical in the environment. The scientific parameters entered include:

- interphase or subcompartment
- geographic area
- quantity/time
- reference

A typical entry is shown in Figure E.C.12.

Photodegradation data include the following:

- medium
- test conditions
- quantity of chemical that degrades
- products and quantity produced
- reference

An example of this type of entry appears in Figure E.C.12.

Hydrolysis data include:

- medium and test conditions
- quantity hydrolysed
- products and quantity produced
- reference

A sample entry appears in Figure E.C.13.

Adsorption refers to the process whereby a chemical adheres (absorbs) to a surface solid (biotic and abiotic). The scientific parameters include:

- medium or adsorbent
- test conditions
- test method and quantity
- reference

Figure E.C.13 shows a typical entry line.

Evaporation data include:

- medium
- test conditions
- quantity evaporated
- reference

A sample of this data is given in Figure E.C.13.

Loss describes the event where a decrease in the concentration of chemical cannot be attributed to a single process. The scientific parameters include:

- medium
- test conditions
- quantity lost
- products and quantity produced
- reference

An example appears in Figure E.C.14.

Model ecosystems are set up to experimentally study the various phenomena which occur in natural ecosystems. The scientific parameters included are as follows:

- type of model ecosystem
- reference

Figure E.C.14 shows a typical entry.

o **Analytical Methods**

Sampling/Preparation/Analysis describes the sampling methods, sample preparation, and analytical methods used to test for the environmental presence of various substances. If the report is detailed, the scientific parameters selected include:

- medium
- analytical method
- detection limit
- sample size
- reference

If a less detailed description is given, the data appear in a section called Sampling/Preparation which includes:

- medium
- analytical method
- reference

- **Removal**

This section is very broad and includes:

Spills - entered as a free-text description of secondary documents prepared by expert committees on the handling of spills.

Poisoning treatment - also entered as a free-text description. It is included to inform the user of the symptoms and treatment of various intoxications.

Removal methods - describe the main procedures for substance removal. These methods include recycling, regeneration and ultimate disposal.

- **Legal Implications**

The Legal mechanisms/Recommendations section concerns the control of substances in the environment. The category is very broad and highlights regulations and guidelines from air quality to cosmetic quality. The scientific parameters include:

- geographic area or organization
- type of mechanism
- subject of mechanism
- description of mechanism
- levels with specified analytical method
- effective date
- reference

C.4 ACCESSIBILITY

IRPTC is not yet in published or computerized form. A manual is available containing sample entries of various chemicals.

C.5 DEVELOPMENT PLANS

It is planned that IRPTC will be an on-line data base as well as in published book form. The data base would be continuously updated. IRPTC will also be available on comfiche-computer generated microfiche.

C.6 REFERENCES

1. IRPTC - Instructions for the Selection and Presentation of Data for the International Register of Potentially Toxic Chemicals with Sixty Illustrative Chemical Data Profiles.

KIRK-OTHMER

Scope:

The Kirk-Othmer Encyclopedia of Chemical Technology is a reference text which covers virtually all major aspects of chemical technology and related topics: industrial products, natural resources, manufacturing processes, and chemical uses. The third edition will include topics such as energy, health, safety, toxicology, new materials, polymer and plastics technology, inorganic and solid-state chemistry, composite materials, fermentation and enzymes, coatings, pharmaceuticals, and surfactant technology.

Second edition volumes were sequentially published from 1963-1972. In the 25 volumes of the third edition, approximately 1,000 articles written by subject experts will appear. The third edition volumes are being issued at a rate of four per year; completion of the set is expected in 1983.

Access:

The Kirk-Othmer Encyclopedia of Chemical Technology is published by Wiley-Interscience, New York (212) 867-9200.

Cost:

The third edition of the Kirk-Othmer Encyclopedia of Chemical Technology is available by subscription for $95 per volume.

Sample Search/Output:

Not applicable.

Introduction

The DIALOG Information Retrieval Service, from DIALOG Information Services, Inc., has been serving users since 1972. Now, with more than 120 databases available on the system, the DIALOG Service offers unequaled subject balance and variety. And the DIALOG searching capabilities and strengths make it the most powerful online system of its type.

The databases on the DIALOG system contain in excess of 45,000,000 records. Records, or units of information, can range from a directory-type listing of specific manufacturing plants to a citation with bibliographic information and an abstract referencing a journal, conference paper, or other original source.

The following chart groups the DIALOG databases in categories representing their primary topic coverage. DIALOG System features are then described, and information on how to begin service is provided. Brief database descriptions follow, giving a clearer picture of not only the individual databases, but also of the scope of subject matter the DIALOG Service offers. A list of databases by file number is found at the end of the Catalog.

File No.	DATABASE (Supplier)	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record
	MULTIDISCIPLINARY AND CURRENT AFFAIRS		
102	★ ASI (Congressional Information Service, Inc.)	$90	15¢
88	★ BIOGRAPHY MASTER INDEX (Gale Research Company)	55	15
137	★ BOOK REVIEW INDEX (Gale Research Company)	55	15
101	CIS (Congressional Information Service, Inc.)	90	25
35	COMPREHENSIVE DISSERTATION INDEX (Univ. Microfilms Inc.)	55	12
77	CONFERENCE PAPERS INDEX (Cambridge Scientific Abstracts)	73	20
135	★ CONGRESSIONAL RECORD ABSTRACTS (Capitol Services, Inc.)	75	15
411	DIALINDEX™ (DIALOG Information Retrieval Service)	35	na
200	DIALOG PUBLICATIONS (DIALOG Information Retrieval Service)	15	na
114	ENCYCLOPEDIA OF ASSOCIATIONS (Gale Research Company)	55	15
20	FEDERAL INDEX (Capitol Services, Inc.)	90	20
136	★ FEDERAL REGISTER ABSTRACTS (Capitol Services, Inc.)	75	20
26	FOUNDATION DIRECTORY (The Foundation Center)	60	30
27	FOUNDATION GRANTS INDEX (The Foundation Center)	60	30
66	GPO MONTHLY CATALOG (U.S. Government Printing Office)	35	10
85	★ GRANTS DATABASE (Oryx Press)	60	30
150	LEGAL RESOURCE INDEX (Information Access Corp.)	90	20
47	MAGAZINE INDEX (Information Access Corp.)	75	20
78	NATIONAL FOUNDATIONS (The Foundation Center)	60	30
111	NATIONAL NEWSPAPER INDEX (Information Access Corporation)	75	20
211	NEWSEARCH (Information Access Corporation)	95	20
911	NEWSEARCH (Information Access Corporation) subscriber	na	na
49	PAIS INTERNATIONAL (Public Affairs Information Service, Inc.)	60	15
65	SSIE CURRENT RESEARCH (Smitheonian Science Info. Exchange)	78	20
	SCIENCE		
110	AGRICOLA 1970–1978 (U.S.D.A. Technical Information Systems)	$30	10¢
10	AGRICOLA 1979–present (U.S.D.A. Technical Information Systems)	30	10
55	BIOSIS PREVIEWS 1969–1973 (Biosciences Information Service)	49	10
5	BIOSIS PREVIEWS 1974–present (Biosciences Information Service)	49	15
2	CA SEARCH 1967–1971 (American Chemical Society)	70	18

File No.	DATABASE (Supplier)	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record
3	CA SEARCH 1972–1976 (American Chemical Society)	$70	18¢
104	CA SEARCH 1977–1979 (American Chemical Society)	70	18
4	CA SEARCH 1978–present (American Chemical Society)	70	18
31	CHEMNAME™ (Chemical Abstracts Service, DIALOG Information Retrieval Service)	70	20
30	CHEMSEARCH™ (Chemical Abstracts Service, DIALOG Information Retrieval Service)	55	16
130	CHEMSIS™ 1977–present (Chemical Abstracts Service, DIALOG Information Retrieval Service)	70	20
131	CHEMSIS™ 1972–1976 (Chemical Abstracts Service, DIALOG Information Retrieval Service)	70	20
50	CAB ABSTRACTS (Commonwealth Agricultural Bureaux)	35	25
72	EXCERPTA MEDICA 1980–present (Excerpta Medica)	65	20
73	EXCERPTA MEDICA IN PROCESS (Excerpta Medica)	65	20
172	EXCERPTA MEDICA 1974–1979 (Excerpta Medica)	65	20
58	GEOARCHIVE (Geosystems)	70	20
89	GEOREF (American Geological Society)	65	20
12	INSPEC 1969–1977 (Institution of Electrical Engineers)	70	20
13	INSPEC 1978–present (Institution of Electrical Engineers)	70	20
76	IRL LIFE SCIENCES COLLECTION (Information Retrieval Ltd.)	45	15
152	* MEDLINE 1966–1974 (U.S. National Library of Medicine)	35	15
153	* MEDLINE 1975–1979 (U.S. National Library of Medicine)	35	15
154	MEDLINE 1980–present (U.S. National Library of Medicine)	35	15
29	METEOROLOGICAL AND GEOASTROPHYSICAL ABSTRACTS (American Meteorological Society and NOAA)	95	15
204	ONTAP™ CA SEARCH (American Chemical Society)	15	na
231	ONTAP™ CHEMNAME (American Chemical Society)	15	na
94	SCISEARCH® 1974–1977 (Institute for Scientific Information) subscriber	40	10
94	SCISEARCH® 1974–1977 (Institute for Scientific Information) nonsubscriber	130	20
34	SCISERACH® 1978–present (Institute for Scientific Information) subscriber	30	10
34	SCISEARCH® 1978–present (Institute for Scientific Information) nonsubscriber	120	25
62	SPIN (American Institute of Physics)	35	10
52	TSCA INITIAL INVENTORY (Environmental Protection Agency, DIALOG Information Retrieval Service)	45	15
	APPLIED SCIENCE & TECHNOLOGY		
45	APTIC (Air Pollution Tech. Info. Ctr. & the Franklin Institute)	$47	20¢
44	AQUATIC SCIENCE & FISHERIES ABSTRACTS (NOAA)	35	15
112	AQUACULTURE (NOAA)	35	15
116	AQUALINE (Water Reserach Centre)	35	30
96	BHRA FLUID ENGINEERING (British Hydromechanics Research Association)	65	15
23	CLAIMS™/CHEM 1950–1970 (IFI/Plenum Data Company)	95	15
223	CLAIMS™/UNITERM 1950–1970 (IFI/Plenum Data Company)	300	15
224	CLAIMS™/UNITERM 1971–1977 (IFI/Plenum Data Company)	300	15
225	CLAIMS™/UNITERM 1978–present (IFI/Plenum Data Company)	300	15
222	CLAIMS™/CITATION (IFI/Plenum Data Company)	95	$50.00
124	CLAIMS™/CLASS (IFI/Plenum Data Company)	95	10
24	CLAIMS™/U.S. PATENTS 1971–1977 (IFI/Plenum Data Company)	95	15

File No.	DATABASE (Supplier)	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record
25	CLAIMS™/U.S. PATENTS ABSTRACTS 1978–present (IFI/Pelnum Data Company)	$95	50¢
125	CLAIMS™/U.S. PATENT ABSTRACTS WEEKLY (IFI/Plenum Data Company)	95	50
8	COMPENDEX (Engineering Index, Inc.)	68	20
60	CRIS/USDA (USDA)	40	10
103	★ DOE ENERGY (U.S. Dept. of Energy)	35	15
69	ENERGYLINE* (Environment Information Center, Inc.)	90	20
40	ENVIROLINE* (Environment Information Center, Inc.)	90	20
68	ENVIRONMENTAL BIBLIOGRAPHY (Internatl. Acad. at Santa Barbara)	60	15
51	FOOD SCIENCE AND TECHNOLOGY ABS. (Intl. Food Info. Service)	65	15
79	FOODS ADLIBRA (K&M Publications, Inc.)	55	10
123	INPADOC (International Patent Documentation Center)	95	20
74	INTERNATIONAL PHARMACEUTICAL ABS. (Am. Soc. of Hospital Pharmacists)	50	15
14	ISMEC (Cambridge Scientific Abstracts)	73	20
32	METADEX (American Society for Metals)	80	12
118	★ NONFERROUS METALS ABSTRACTS (British Non-Ferrous Metals Technology Center)	45	20
6	NTIS (National Technical Info. Service, U.S. Dept. of Commerce)	40	10
28	OCEANIC ABSTRACTS (Cambridge Scientific Abstracts)	73	20
48	PIRA (Research Assoc. for Paper & Board, Printing & Packaging Indus.)	55	15
41	POLLUTION ABSTRACTS (Cambridge Scientific Abstracts)	73	20
95	RAPRA ABSTRACTS (Rubber and Plastics Research Association of Great Britain)	65	15
117	★ SELECTED WATER RESOURCES ABSTRACTS (U.S. Dept. of the Interior)	45	15
115	SURFACE COATINGS ABSTRACTS (Paint Research Association of Great Britain)	65	15
63	TRIS (U.S. Department of Transportation and Transportation Research Board)	40	10
99	WELDASEARCH (The Welding Institute)	65	15
33	WORLD ALUMINUM ABSTRACTS (American Society for Metals)	50	10
67	WORLD TEXTILES (Shirley Institute)	55	10
	SOCIAL SCIENCES & HUMANITIES		
9	AIM/ARM (Center for Vocational Education)	$25	10¢
38	AMERICA: HISTORY & LIFE (ABC-Clio, Inc.)	65	15
56	ARTBIBLIOGRAPHIES MODERN (ABC-Clio, Inc.)	60	15
64	CHILD ABUSE AND NEGLECT (Natl. Cntr. for Child Abuse and Neglect)	35	10
1	ERIC (Educational Resources Information Center)	25	10
54	EXCEPTIONAL CHILD ED. RESOURCES (Council for Except. Children)	25	10
39	HISTORICAL ABSTRACTS (ABC-Clio, Inc.)	65	15
36	LANGUAGE & LANGUAGE BEHAVIOR ABS. (Sociol. Abs., Inc.)	55	15
61	LISA (Learned Information Ltd.)	50	10
71	MLA BIBLIOGRAPHY (Modern Language Association)	55	15
21	NCJRS (National Criminal Justice Reference Service)	35	15
46	NICEM (National Information Center for Educational Media)	70	20
70	NICSEM/NIMIS (National Info. Cntr. for Special Education Materials)	35	10
86	★ MENTAL HEALTH ABSTRACTS (National Clearinghouse for Mental Health Information, National Institute of Mental Health)	30	10
201	ONTAP™ ERIC	15	na

File No.	DATABASE (Supplier)	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record
57	PHILOSOPHER'S INDEX (Philosophy Documentation Center)	$55	15¢
91	POPULATION BIBLIOGRAPHY (University of North Carolina, Carolina Population Center)	55	10
11	PSYCINFO (American Psychological Assoc.)	65	10
97	RILM ABSTRACTS (City University of New York, International RILM Center)	65	15
7	SOCIAL SCISEARCH® (Institute for Scientific Information)	70	10
37	SOCIOLOGICAL ABSTRACTS (Sociological Abstracts, Inc.)	55	15
87	SPECIAL EDUCATION MATERIALS (NICSEM)	65	15
93	U.S. POLITICAL SCIENCE DOCUMENTS (Univ. of Pittsburgh, Cntr. for International Studies)	65	15
120	U.S. PUBLIC SCHOOL DIRECTORY (National Center for Educational Statistics)	35	10
	BUSINESS/ECONOMICS		
15	ABI/INFORM (Data Courier, Inc.)	$73	30¢
43	★ ADSEARCH (Corporate Intelligence, Inc.)	95	25
19	CHEMICAL INDUSTRY NOTES (American Chemical Society)	75	20
100	DISCLOSURE (Disclosure Incorporated)	60	$5.00
90	ECONOMICS ABSTRACTS INTERNATIONAL (Learned Information Ltd.)	65	20
22	EIS INDUSTRIAL PLANTS (Economic Information Sytems, Inc.)	90	50
92	EIS NONMANUFACTURING ESTABLISHMENTS (Economic Information Systems, Inc.)	90	50
105	FOREIGN TRADERS INDEX (U.S. Department of Commerce)	45	25
59	FROST & SULLIVAN DM^{2} (Frost & Sullivan)	90	20
80	LABOR STATISTICS (LABSTAT) (Bureau of Labor Statistics, U.S. Dept. of Labor)	45	15
75	MANAGEMENT CONTENTS® (Management Contents, Inc.)	70	15
42	PHARMACEUTICAL NEWS INDEX (Data Courier, Inc.)	90	20
98	PTS F&S INDEXES 1972–1975 (Predicasts, Inc.)*	90	20
18	PTS F&S INDEXES 1976–present (Predicasts, Inc.)*	90	20
84	PTS INTERNATIONAL TIME SERIES (Predicasts, Inc.)*	90	20
83	PTS INTERNATIONAL FORECASTS (Predicasts, Inc.)*	90	20
17	PTS PREDALERT (Predicasts, Inc.)*	90	20
16	PTS PROMT (Predicasts, Inc.)*	90	20
81	PTS U.S. FORECASTS (Predicasts, Inc.)*	90	20
82	PTS U.S. TIME SERIES (Predicasts, Inc.)*	90	20
132	STANDARD & POOR'S NEWS (Standard & Poor's Corp.)	85	15
106	TRADE OPPORTUNITIES (U.S. Department of Commerce)	45	25
107	TRADE OPPORTUNITIES WEEKLY (U.S. Department of Commerce)	45	50
126	U.S. EXPORTS 1978–present (U.S. Department of Commerce)	45	25

*After a three-month trial period the rate per record TYPEd or PRINTed will increase to 50¢ unless subscription arrangement is made through Predicasts, Inc., 200 University Circle Research Center, 11001 Cedar Ave., Cleveland, OH 44106 (216/795-3000)

★Forthcoming database

DRAFT

D6303000107

Multimedia Assessment of the Inorganic Chemicals Industry

Acronym: None
Media sampled to generate data: Effluents manufacturing processes and waste treatment
Emissions manufacturing processes and waste treatment
Solid waste
Type of data collection/monitoring: Point source data collection inorganic chemical manufacturing processes

Data base status: Update terminated

ABSTRACT: Information on high volume, industrial inorganic chemicals which are compounds of aluminum, boron, chromium, fluorine, iron, manganese, nickel, phosphorus, seawater, silicon, methane, alkalie, sodium, sesquicarbonate, sulfur, titanium, barium, calcium, copper, lead, strontium, potassium, lithium, magnesium, arsenic, antimony, cadmium, cobalt, mercury, vanadium, and four industrial gases. Process description, energy requirements, raw waste description, pollution technology, and emissions after controls are also included. Occupational and health effects and research and development needs in pollution control are presented for each group of chemicals.

Non-pollutant parameters include:
- Chemical data
- Compliance data
- Concentration measures
- Cost/economic data
- Discharge points
- Disposal
- Exposure data
- Flow rates
- Geographic subdivision
- Health effects
- Industry
- Location
- Manufacturer
- Political subdivisions
- Production levels
- Treatment devices
- Use
- Volume/mass measures
- Process description
- Control technology
- Residual emissions after treatment
- disposal practices

Ongoing study time period is 01/01/75 to 08/30/80
Termination of data collection: Occurred 08/30/80

Frequency of data collection: 5 year period for data collection and update

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DRAFT

Every plant used in the U.S. to manufacture inorganic chemicals.

Data base includes: Summary or aggregate observations
Reference data/citations

Every facility manufacturing inorganic chemicals on an industrial scale

Geographic coverage of data base: National
Location identifiers of station/source for each record are: State
City
Town/township

Facility identifiers include: Plant location
Parent corporation name
Pollutant identification data are: Uncoded

Limitations: Limitation of data base is that representative manufacturers were contacted and engineering estimates were made for others.

Lab audit: Data not based on lab analysis.
Precision and accuracy estimates are not available
No known edit procedures exist.

Data collected by: Contractor - Versar, Inc. Springfield, VA
Data analyzed by: EPA lab - Industrial Environmental Research Lab-Cinci
Contractor - Versar, Inc. Springfield, VA
Data base identifies specific laboratory performing analysis.

Anticipatory/research is the primary purpose for data collection.
Technology development is the secondary purpose for data collection.
Trend assessment is the third purpose for data collection.
No statutory requirement: Data collection requirement is to develop long term research and development program for inorganic chemical industry
Form of available reports and outputs: Unpublished reports Multimedia Assessment of Inorganic Chemicals Industry.
Printouts on request possible in a year
Current regular users of data base: 5
Users: EPA headquarter offices - Effluent Guidelines Division
EPA regional offices
Federal agencies Occupational Safety and Health Administration
Confidentiality: No limits on access to data
Primary physical location of data: EPA lab
Form of data storage: Magnetic tape
Data access: Commercial software SYSTEM 2000
EPA hardware Univac 1100

Contact - Subject matter:Mary Stinson (201) 340-6683
Contact - Computer-related: Mary Stinson (201) 340-6683
Contact - responsible EPA Office: Industrial Environmental Research Lab-Cincin (513) 684-4481

Charge for non-EPA use: Not Known at this time
Frequency of master file up-date: Annual update may be done

D7205000002

National Electronic Injury Surveillance System

Acronym: NEISS
Media sampled to generate data: sample is hospital emergency rooms which treat pesticide poisonings.
Type of data collection/monitoring: monitoring of injuries (pesticide poisonings) treated in hospital emergency rooms.
Data base status: Operational/ongoing

ABSTRACT: NEISS consists of a listing of pesticide poisoning incidents giving information on type of pesticide, route of exposure, whether or not the case was diagnosed as a poisoning by a physician, what symptoms, if any, were present, the brand name of the pesticide, and the EPA registration number of the product, if known.

Non-pollutant parameters include:
- Exposure data
- Health effects
- Location
- Population demographics
- Sampling date
- Treatment devices
- pesticide type
- route of exposure
- physician diagnosis of poisoning
- symptoms present
- age & sex of patient
- disposition of case
- body part affected
- EPA regulation number

Ongoing study time period is 01/01/79 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: Monthly reports by Consumer Product Safety Commission to EPA

Total estimated number of observations is 21067.
Estimated annual increase of observations is 18500.

Data base includes: Raw data/observations
Summary or aggregate observations

Total number of stations or sources covered is 74.
Number currently contributing data is 51.
Number of facilities covered is 74.

Geographic coverage of data base: National
Location identifiers of station/source for each record are: County

State (available to
Health Effects Branch
only)

Facility identifiers include: hospital identification number assigned by Consumer Product Safety Commission

Pollutant identification data are: Coded with other coding schemes

Limitations: Data base contains only those pesticides and RPAR chemicals that are no longer being sold but that may still exist in homes throughout the country.

Data collection and analysis procedures: Sampling plan documented
Analysis method documented
Lab analysis not based on EPA-approved or accepted methods.
Lab audit: Data not based on lab analysis.
Precision and accuracy estimates exist but are not included in data base
Edit procedures used but undocumented.

Data collected by: hospital personnel
Data analyzed by: Other federal agency - U.S. Consumer Product Safety Commission (CPSC)
Data base does not identify specific laboratory performing analysis.

Development of regulations or standards is the primary purpose for data collection.
Trend assessment is the secondary purpose for data collection.
Special study is the third purpose for data collection.
No statutory requirement: Data collection requirement is to support Agency research into health effects of pesticides.
Form of available reports and outputs: Unpublished reports Report of First Year Data-Interagency Agreement with the Consumer Product Safety Commission
Current regular users of data base: 5
Users: EPA headquarter offices - Health Effects Branch, Office of Pesticide Programs
EPA laboratories Pesticide Incident Monitoring System (PIMS) Data Center, Miami FL.
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: Other federal agency
Form of data storage: Magnetic disc
Data access: through the Health Effects Contact with the Consumer Product Safety Commission

Contact - Subject matter: Mary Frankenberry (202)472-9310
Contact - Computer-related: Eileen Kessler, CPSC
Contact - responsible EPA Office: Mary Frankenberry (202)472-9310

Charge for non-EPA use: No outside use/access permitted
Frequency of master file up-date: Semi-annually
report annually

Related non-EPA data bases: reports from Poison Control Centers

D2209000905

National Institutes of Health/Environmental Protection Agency (NIH/EPA) Chemical Information System

Acronym: CIS

Media sampled to generate data: Air
Atmospheric deposition
Blood
Drinking water
Effluents various
Emissions various
Ground water
Mobile source emissions
Noise
Runoff various
Sediment
Soil
Solid waste
Surface water various
Tissue various

Type of data collection/monitoring: ambient, point and non-point sources
Data base status: Operational/ongoing

ABSTRACT: The NIH/EPA Chemical Information System (CIS) is a collection of scientific data bases available through an interactive computer program. No other publicly available information system can provide such diverse numeric, as opposed to bibliographic, data on so many (over 192,000) chemical substances. CIS has a unique linking system, the heart of which is the Structure and Nomenclature Search System (SANSS). SANSS allows the user, in a single operation, to search 66 different files including the TSCA inventory. CIS includes 6 major identification data bases (CHM-TADS; Mass Spectometry; Carbon 13 NMR; Organic Crystals: Single Crystals and Powder Defraction). Additional data bases cover toxicology, the Federal Register, and bibliographic files.

Non-pollutant parameters include: Biological data
Chemical data
Collection method
Compliance data
Concentration measures
Cost/economic data
Discharge points
Disposal
Geographic subdivision
Health effects
Industry
Inspection data
Location
Manufacturer
Physical data
Sampling date
Site description
Temperature

Use
Volume/mass measures

Ongoing study time period is 01/01/30 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection:
- one time only
- daily
- weekly
- quarterly
- semi annually
- annually
- as needed

Total actual number of observations is 192000 chemicals.
Estimated annual increase of observations is 25000-50000.

Data base includes:
- Raw data/observations
- Summary or aggregate observations

Total number of stations or sources covered is 1000.
Number currently contributing data is 66.

Geographic coverage of data base: International
Location identifiers of station/source for each record are:
- State
- County
- City
- Town/township
- Street address
- Coordinates
- latitude/longitude in Waterdrop data base
- Project identifier
- lab identifier

Facility identifiers include:
- Plant facility name
- Plant location
- Parent corporation name
- Parent corporation location
- Street address
- SIC code

Pollutant identification data have: CAS registry number codes

Limitations: Quality assurance procedures vary by data base and source. Frequency of data collection varies for each data base and source.

Data collection and analysis procedures:
- Sampling plan documented
- Collection method documented
- Analysis method documented
- QA procedures documented

Lab analysis not based on EPA-approved or accepted methods.
Lab audit: Data not based on lab analysis.
Precision and accuracy estimates partially exist for organic crystals and

mass spectometry data
Edit generally performed by contractor, some documented, and some not.

Data collected by: Local agency - Texas, California and other Air Resources Boards
State agency - Environmental Protection Agencies
Regional office - Surveillance and Analysis Divisions (most regions)
EPA lab - Environmental Monitoring and Support Lab-Cincinnati, OH
EPA lab - Environmental Research Lab-Athens, GA
EPA lab - Environmental Research Lab-Ada, OK
EPA lab - National Enforcement Investigations Center
Contractor lab - under contract to National Bureau of Standards, & Radian Lab under contract to EPA.
Contractor - Betel, RTI and misc. others
Other federal agency - National Institutes of Health Federal Drug Administration National Bureau of Standards
EPA headquarters - Chemical Information System coordinator
Universities, Data Center (England), Hungarian Academy of Sciences & others
Data analyzed by: Contractor - Fein Marquart & Radian Corporation
international data generators
Data base identifies specific laboratory performing analysis.

Development of regulations or standards is the secondary purpose for data collection.
Compliance or enforcement is the secondary purpose for data collection.
Trend assessment is the secondary purpose for data collection.
Technology development is the secondary purpose for data collection.
Risk assessment is the secondary purpose for data collection.
Anticipatory/research is the secondary purpose for data collection.
Program evaluation is the secondary purpose for data collection.
development of single resource to link chemical files and literature. Purpose of use varies by user. is the primary purpose for data collection.
No statutory requirement: Data collection requirement is to develop a support resource to coordinate and link all EPA chemical files with the literature & external files.
Form of available reports and outputs: Publications articles in *On-Line*; *Sciences*; *Industrial Chemical News*; *Journal of Chemical Information and Computer Systems*.
mass spectra data (4 volumes and index)
Current regular users of data base: 1000
Users: EPA headquarter offices - Office of Planning and Evaluation
EPA headquarter offices - Office of Toxic Substances
EPA headquarter offices - Office of Enforcement
EPA headquarter offices - Office of Waste Water Management
EPA headquarter offices - Office of Solid Waste
EPA headquarter offices - Office of Research and Development
EPA headquarter offices - Office of Air, Noise and Radiation
EPA regional offices
EPA laboratories
Other federal agencies

States
industry, universities and 20 countries
Confidentiality: No limits on access to data
Primary physical location of data: Contractor
Form of data storage: Magnetic tape
Magnetic disc
Data access: EPA software NIH/EPA-CIS MIDSD system number: 7500000900
EPA hardware DEC PDP-10 (NIH)

Contact - Subject matter: Stephen R. Heller (202)755-4938
Contact - Computer-related: Stephen R. Heller (202)755-4938
Contact - responsible EPA Office: Stephen R. Heller (202)755-4938

Charge for non-EPA use: yes
Frequency of master file up-date: varies from weekly to annually by data base

Related EPA data bases: OHM-TADS, STORET
Related non-EPA data bases: Lockheed bibliographic data bases, National Library of Medicine data bases, System Development Corporation data bases.

Person completing form: Stephen R. Heller
Office: EPA/(OPM)/(OMAS)/(MIDSD)
Address: 401 M St, S.W. Washington, DC 20460
Phone: (202)755-4938

Pollutants included in data base:
acetaldehyde 75-07-0
acrolein 107-02-8
acrylonitrile 107-13-1
allyl chloride 107-05-1
benzyl chloride 100-44-7
bis(chloromethyl)ether 542-88-1
carbon tetrachloride 56-23-5
chlorobenzene 108-90-7
chloroform 67-66-3
chloroprene 126-99-8
dichloromethane 75-09-2
dimethylnitrosamine 62-75-9
dioxane 123-91-1
dioxin 828-00-2
epichlorohydrin 106-89-8
ethylene dibromide (edb) 106-93-4
ethylene dichloride 107-06-2
ethylene oxide 75-21-8
formaldehyde 50-00-0
hexachlorocyclopentadiene 77-47-4
m-cresol 108-39-4
m-xylene 108-38-3
maleic anhydride 108-31-6
manganese 7439-96-5
methyl chloroform 71-55-6

Table 5. Profile of data collection systems that measure environmental pollutants or individual exposures—Con.

(Agency designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
National Occupational Hazard Survey	NIOSH	To provide estimates of the number of workers exposed to various industrial compounds.		Occupation. Standard Industrial Classifications. Trade name product, and chemical ingredient.	Exposure survey. Probability sample of industrial sites within 60 industries. Plants are stratified by size within an industry. Plants are randomly sampled within strata and all plant employees interviewed.	4,636 plants throughout the United States were surveyed between 1972 and 1974. A second survey is underway.	Tape. Publication.	Estimates of number of workers exposed to specific chemicals by industrial code.

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OCCUPATIONAL
HAZARD

SURVEY
SURVEY
SURVEY
SURVEY
SURVEY

VOLUME 1

SURVEY MANUAL

NIOSH
NIOSH
NIOSH
NIOSH

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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SURVEY
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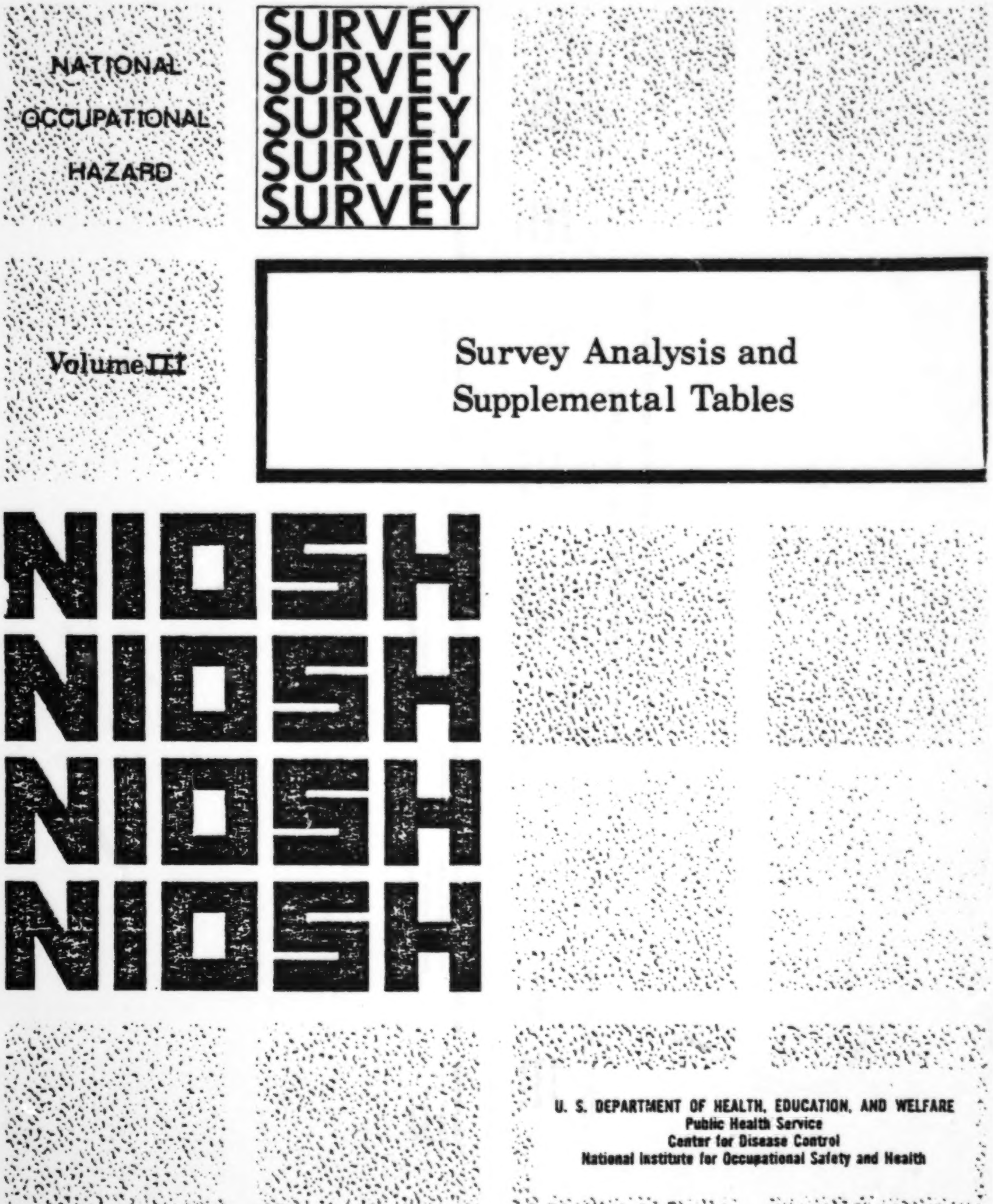
SURVEY

Volume II

Data Editing and Data Base Development

NIOSH
NIOSH
NIOSH
NIOSH

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health



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Volume III

Survey Analysis and Supplemental Tables

NIOSH
NIOSH
NIOSH
NIOSH

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

Table 2. Profile of data collection systems that document medical care need or use—Con.

(Agency designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissem-ination	Statistics generated
			Health	Environment or individual exposure				
Occupational Hazard Exposure Registry	NIOSH	To provide surveillance of workers exposed to workplace hazards, e.g., kepone.	Presence of expected health effects.	Type of industry and work history indicating potential and actual exposure.	Registry. Continuing search for high-risk groups.	Nationwide effort started in 1976.	None.	Cause specific mortality.

Table 1. Profile of data collection systems that measure population health status—Con.

(Agency designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
Occupationally Related Disease Case Registers	NIOSH	To provide data on the changing incidence and prevalence of occupationally related disease.	Vital and general health status. Occurrence of hepatic angiosarcoma; occurrence of beryllium related disease.	Record of PVC exposure by job history. Record of beryllium exposure by job history.	National case finding efforts. Submission of case reports from medical community. Related to Hepatic Angiosarcoma Case Finding Effort (table	80 cases of angiosarcoma reported for 1974-80. 880 cases of berylliosis reported between 1951 and 1980.	Publications in preparation.	Changes in incidence and prevalence over the years.

D6303000106

Organic Chemical Producers Data Base

Acronym: OCPDB
Media sampled to generate data: No specific media This data base lists organic chemicals, their properties, producers, and describes processes by which they are produced.
Type of data collection/monitoring: literature and personal contacts
Data base status: Operational/ongoing

ABSTRACT: The data base includes almost 600 chemicals and their more than 1,300 producers. Chemicals are described by Chemical Abstracts Services (CAS) registry number, Wiswesser Line Notation (WLN), chemical uses, synonyms, toxicity data, economic data, and producers. Locations of producers are described by city, state, EPA region, and river basin. The chemicals that are produced at each location are listed, along with nameplate capacities and emissions when available.

Non-pollutant parameters include:
- Chemical data
- Cost/economic data
- Discharge points
- Geographic subdivision
- Industry
- Location
- Manufacturer
- Political subdivisions
- Production levels
- Use
- toxicity data
- process descriptions

Ongoing study time period is 02/01/76 to 02/30/79
Termination of data collection: Not anticipated

Frequency of data collection: as needed

Total estimated number of observations is 2492.

Data base includes:
- Raw data/observations
- Summary or aggregate observations
- Reference data/citations

Total number of stations or sources covered is 1246.
Number currently contributing data is 1246.
Number of facilities covered is 1246.

Geographic coverage of data base: National
Location identifiers of station/source for each record are:
- State
- City
- Town/township

Facility identifiers include:
- Plant facility name
- Plant location

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Parent corporation name
Parent corporation location
Program identifier
Pollutant identification data have: CAS registry number codes

Limitations: The data base includes high volume, organic chemical products are included, exclusively. Quality assurance aspects are not applicable.

Data collection and analysis procedures: Collection method documented
Analysis method documented
QA procedures documented
Lab audit: Data not based on lab analysis.
Edit procedures used but undocumented.

Data collected by: Contractor lab - Monsanto, Radian
Data analyzed by: Contractor - Radian
Data base does not identify specific laboratory performing analysis.

Development of regulations or standards is the primary purpose for data collection.
Trend assessment is the secondary purpose for data collection.
No statutory requirement: Data collection requirement is To compile a list of producers of major chemicals in order to facilitate EPA sampling programs and inventories.
Form of available reports and outputs: Publications
Unpublished reports
Printouts on request
Machine-readable raw data
Current regular users of data base: 50
Users: EPA headquarter offices - Office of Toxic Substances
EPA headquarter offices - Office of Solid Waste
EPA headquarter offices - Office of Air Quality Planning and Standards
EPA regional offices
EPA laboratories
Other federal agencies
States
local government agencies

Confidentiality: No limits on access to data
Primary physical location of data: NCC/UNIVAC
Form of data storage: Magnetic tape
Data access: Commercial software System 2000

Contact - Subject matter: A. McBath (513) 684-4417
Contact - Computer-related: A. McBath (513) 684-4417
Contact - responsible EPA Office: E.E. Berkau (513) 684-4314

Charge for non-EPA use: no
Frequency of master file up-date: as needed

Other pertinent data bases: Several are proposed by this office — some of which should be operational by 1982.

Table 3. Profile of data collection systems that test specific interrelationships—Con.

(Agency designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
					persons.			
Outcome Studies of Workers in Selected Industries or Occupations	NIOSH	To understand relationship between type of industry or specific exposures and causes of death.	Cause of death.	Occupation, industry, chemical or physical agent.	Cohort studies. Plants with high-risk characteristics are selected. All workers in a defined cohort are selected for study.	Series of industrywide studies, beginning in 1971.	Special reports.	Risk statistics. Mortality rates. Average exposure to selected pollutants.

Pesticides Analysis Retrieval and Control System (PARCS) EISD #10083

- **Purpose:**

The Office of Pesticide Programs (OPP) is responsible for registration of all pesticides used in the nation. PARCS provides a centralized source of information on all of these registered pesticides. Data in the system are used for registration analysis, research, and reporting.

- **Annual Cost:**

Computer	*Personnel*	*Contract Support*
$500,000	$317,000	$75,000

- **Primary Users:**

The system is used chiefly to support the pesticides registration program. Research on chemicals used in pesticides is also a major source for retrieval requests.

- **Description:**

Currently, information on 36,000 pesticides handled in interstate commerce is contained in the PARCS system. Data in this system is highly encoded: for ease and manipulation, and all new data requests are controlled by one central office.

The PARCS system is used to retrieve information about pesticides on a variety of categories. For example, the system can answer questions such as "list all disinfectants and fungicides containing malathion." The system maintains information on the name and address of producer, ingredients (both active and inert), and the usage category of all pesticides. Retrieval software allows the data to be extracted, analyzed, and formatted. Accident investigation information is also maintained as a separate part of the system.

- **Operation:**

PARCS runs on the OSI computer. The data files are stored on-line, but access to them is limited to retrieval requests submitted to OPP. Retrievals are currently being run about 500 times per year, which is up sharply from previous years. The workload to maintain the data has increased 30-40% this year due to new legislation requiring that intra-state as well as inter-state pesticides be registered.

Input for changes to the data is done using WYLBUR data sets. This input accounts for 40% of the annual costs. Retrievals are run in batch mode. Accident information is maintained in a separate file. Data entered by the Regions is edited and stored on disk. Requests for information on accidents average one per week. Standard summary reports are produced monthly.

- **Responsibility.**

System Sponsor: Elgin Fry

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D7202000005

Pesticide Document Management System

Acronym: PDMS
Media sampled to generate data: Air
Drinking water
Effluents varies by producer
Ground water
Runoff rain water, ground water, waste water
Sediment
Soil
Surface water
Tissue animals, plants, man
Type of data collection/monitoring: scientific data varies as submitted by producers
Data base status: Operational/ongoing

ABSTRACT: The Federal Insecticide, Fungicide, and Rodenticide Act requires every pesticide manufacturer or producer to submit scientific data to EPA before a pesticide product can be manufactured, sold, or used in the United States. These data are maintained in the Pesticide Document Management System. Related information from the published literature is also included.

Non-pollutant parameters include: Biological data
Chemical data
Cost/economic data
Disposal
Exposure data
Health effects
Manufacturer
Physical data
Production levels
Site description
Test/analysis method
Use

Ongoing study time period is 01/01/80 to 10/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: daily

Total estimated number of observations is 65000 citations.
Estimated annual increase of observations is 48000.

Data base includes: Raw data/observations
Summary or aggregate observations
Reference data/citations

Total number of stations or sources covered is 44941 companies.
Number currently contributing data is unknown.

Number of facilities covered is not available.

Geographic coverage of data base: National
Location identifiers of station/source for each record are: citations
Facility identifiers include: Not applicable
Pollutant identification data have: Shaughnessy Codes

Limitations: The data base is still being developed. Currently, it has limited access-batch mode by a chemical code, Shaughnessy Code; a limited number of standard retrievals and output formats; a response time of 3-4 days; and one purpose-information support to the EPA Pesticides Program. Information Requests which fall outside of these limits will require new programs and increase the response time. It contains information for 72 chemicals.

Data collection and analysis procedures: Sampling plan documented
Collection method documented
Analysis method documented
QA procedures documented
Lab analysis not based on EPA-approved or accepted methods.
Precision and accuracy estimates are not available.
Edit Programs for validity of bibliographic information only; no edits for accuracy.

Data collected by: Self reporting pesticide producers and manufacturers
EPA headquarters - Office of Pesticide Programs
Data analyzed by: Self reporting primary data analysis
EPA headquarters - Office of Pesticide Programs
Data base identifies specific laboratory performing analysis.

Development of regulations or standards is the primary purpose for data collection.
Compliance or enforcement is the secondary purpose for data collection.
Risk assessment is the third purpose for data collection.
Statutory authorization is P L 92-516 as amended, section 3(c)(2)(c) (FIFRA)
Form of available reports and outputs: Printouts on request
Microfilm
Current regular users of data base: 350 people (OPP review Scientists and contract reviewers)
Users: EPA headquarter offices - Office of Pesticide Programs
Confidentiality: Limits on access within EPA and outside agency for some data
Primary physical location of data: Headquarters office
Form of data storage: Magnetic disc
Microfich/film
Data access: Commercial software WYLBUR
EPA hardware IBM 370/168 MIDSD system number: 7200000905

Contact - Subject matter:William C. Grosse (202) 426-2680
Contact - Computer-related: Elgin G. Fry (202) 426-8862
Contact - responsible EPA Office: William C. Grosse (202) 426-2680

Charge for non-EPA use: no outside use/access permitted
Frequency of master file up-date: Weekly

D7205000003

Pesticide Incident Monitoring System

Acronym: PIMS

Media sampled to generate data: Air
Blood
Drinking water
Ground water
Runoff agricultural
Sediment
Soil
Tissue human, animal, fish

Type of data collection/monitoring: data collection or monitoring is often determined by the nature of the incident.

Data base status: Operational/ongoing

ABSTRACT: The Pesticide Monitoring System (PIMS) enters, stores, coordinates and retrieves pesticide incident data within the EPA. The system develops and maintains reporting sources, monitors suspected incidents and provides confirmatory analysis and data on circumstances of the incident.

Non-pollutant parameters include: Biological data
Chemical data
Collection method
Concentration measures
Disposal
Exposure data
Geographic subdivision
Health effects
Industry
Location
Manufacturer
Physical data
Precipitation
Sampling date
Site description
Use
Wind direction
Wind velocity
Some application methods
Rates

Ongoing study time period is 01/01/66 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: varies as incidents are reported-may be as frequently as daily.

Total actual number of observations is 41000.
Estimated annual increase of observations is 4000.

Data base includes: Raw data/observations
Summary or aggregate observations

Total number of stations or sources covered is 100 or more.
Number currently contributing data is 50 major contributors.

Geographic coverage of data base: National
Location identifiers of station/source for each record are: State
County
City
Project identifier
Agency or reporting source

Pollutant identification data are: Coded with other coding schemes

Limitations: Pesticides with most reported incidents are those with high agricultural and home use rates. No incidents have been reported for some of the pesticides. PIMS is a voluntary system--as such, numbers of reports vary as does the quality (e.g. confirmed as to pesticide cause.)

Lab analysis based on EPA-approved or accepted methods.
Lab audit: Data not based on lab analysis.
Precision and accuracy estimates exist but are not included in data base
Edit automated data processing system undergoing edit..

Data collected by: Self reporting
Local agency
State agency3 state health departments are among the 12 field offices collecting 90% of the reports.
Regional office
EPA lab
Contractor lab
Contractor9 universities are among the 12 field offices - collecting 90% of the reports.
Other federal agency
EPA headquarters

Data analyzed by: Local agency
State agency
Regional office
EPA lab
Contractor lab
Contractorcooperative agreement with the University of Miami, School of Medicine-operates PIMS
Other federal agency
EPA headquarters

Data base identifies specific laboratory performing analysis.

Trend assessment is the primary purpose for data collection.
Risk assessment is the primary purpose for data collection.
Development of regulations or standards is the primary purpose for data collection.
Special study is the primary purpose for data collection.
Compliance or enforcement is the secondary purpose for data collection.

Anticipatory/research is the secondary purpose for data collection.
Program evaluation is the secondary purpose for data collection.
Statutory authorization is P L 92-516 as amended, Section 3 (The Federal Insecticide, Fungicide, and Rodenticide Act-FIFRA)
OMB form number: 158-R-0008
Form of available reports and outputs: Publications summary reports
Unpublished reports
Printouts on request
Current regular users of data base: 50
Users: EPA headquarter offices - Office of Pesticide Programs, Office of General Counsel, Office of Pesticides and Toxic Substances, Office of Enforcement
EPA regional offices
Other federal agencies
States
General Accounting Office
Public Interest Groups various ones
Confidentiality: Limits on outside access for all data
Primary physical location of data: Contractor
Form of data storage: Magnetic disc
Original form (hardcopy, readings)
Data access: University of Miami, IBM Series I

Contact - Subject matter: James J. Boland (202)472-9310
Contact - Computer-related: Dr. Robert Duncan (305)547-6475
Contact - responsible EPA Office: Hazard Evaluation Division, Office of Pesticide Programs (202)472-9310

Charge for non-EPA use: No
Frequency of master file up-date: daily

Person completing form: James J. Boland
Office: EPA/(OPTS)/(OPP)/(HED)
Address: Marfair Bldg., Washington, DC
Phone: (202)472-9310

Pollutants included in data base:
acrolein 107-02-8
acrylonitrile 107-13-1
carbon tetrachloride 56-23-5
chloroform 67-66-3
dichloromethane 75-09-2
ethylene dibromide (edb) 106-93-4
ethylene oxide 75-21-8
formaldehyde 50-00-0
m-cresol 108-39-4
methyl chloroform 71-55-6
o-cresol 95-48-7
p-cresol 106-44-5
p-dichlorobenzene 106-46-7
perchloroethylene 127-18-4
phosgene 75-44-5
proplyene oxide 75-56-9

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Risk Analysis

AN INTERNATIONAL JOURNAL

An Official Publication of the Society for Risk Analysis

Plenum Press • New York and London

Table 2. Profile of data collection systems that document medical care need or use

(Agecny designations by acronym are listed in figure 1)

Name of program or system	Agency	Purpose	Topical focus of data		Method of data collection	Population-location-time coverage	Method of data dissemination	Statistics generated
			Health	Environment or individual exposure				
BLS Statistical Record-keeping System	BLS	To provide registration of occupational illness and injury at the employer level.	Fatalities. Disease and injury by cause.	Industry.	Registry. Log and summary of occupational injury and illness are maintained. Supplementary record on each case.	Since 1971, logs have been maintained by all nonfarm employers of more than 10 people nationwide.	Publication.	Incidence of injury and illness by cause per 100 workers.

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4801 Woodway Drive
Houston, TX 77056
713/840-8093, 8095 or 8099

SDC Search Service
Suite 301BIS
28 Boulevard de Grenelle
Paris, France 75015
33(1) 575-5775
Telex: 20116F SYDECO

7929 Westpark Drive
McLean, VA 22101
703/790-9850

122 East 42nd Street, Suite 1750
New York, NY 10017
212/697-5120

5680 S. Syracuse Circle, Suite 300
Englewood, CO 80111
303/770-3294

INFOMART
Village By The Grange 122 St. Patric Street
Toronto, Ontario M5T 2X8 Canada
416/598-4000

System Development Corporation of Japan, Ltd.
Kakuei Building
24-5, Sakuragaoka-Cho, Shibuya-Ku
Tokyo, 150 Japan
03/461-5261
Telex: J23405 SDCJ

Toll Free Numbers: 800/352-6689 (CA), 800/421-7229 (continental U.S. except CA)
Telex: 65-2358—TWX: 910/343-6443

DATA BASE CONTENT

DATA BASE	SCIENCE & TECHNOLOGY	SOCIAL SCIENCE	BUSINESS
ACCOUNTANTS INDEX		X	X
AGRICOLA	X		X
APILIT	X		
APIPAT	X		X
ASI	X	X	X
BIOCODES	X		
BIOSIS & BIO6973	X		
CAS77 & CAS7276	X		
CBPI		X	X
CDI	X	X	X
CHEM7071	X		
CHEMDEX	X		
CIN	X		X
CIS INDEX	X	X	X
CNI		X	X
COMPENDEX	X		X
CONFERENCE PAPERS INDEX	X		
CRDS	X		
CRECORD	X	X	X
ENERGYLINE	X	X	X
ENVIROLINE	X	X	
ERIC	X	X	X
FEDREG	X	X	
FSTA	X		X
GeoRef	X		
GRANTS	X	X	X
INFORM		X	X
INSPEC & INSP6976	X		
ISMEC	X	X	X
LABORDOC		X	X
LIBCON	X	X	X
LISA	X	X	
MANAGEMENT		X	X
NEWSPAPER INDEX	X	X	X
NTIS	X	X	X
OCEANIC	X		
PAPERCHEM	X		X
P/E NEWS	X		X
PESTDOC	X		
POLLUTION	X	X	
PROMT			X
PSYCH ABSTRACTS		X	
QUEBEC-ACTUALITE			X
RINGDOC	X		
SAE	X		X
SAFETY SCIENCE ABSTRACTS	X	X	
SOCIAL SCIENCE CITATION INDEX		X	
SSIE	X	X	X
TITUS	X		
TULSA	X		X
U.S. POLITICAL SCIENCE DOCUMENTS		X	
WPI	X		X

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THE FOLLOWING IS A COMPLETE LIST OF ALL DATABASE CONNECT HOUR AND PRINT CHARGES. POSTAGE WILL BE CHARGED FOR ALL OFFLINE PRINTS.

		CONNECT ($/HR)	OFFLINE PRINTS PRT/PRT FULL OR TAILORED	ONLINE PRINTS PRT/PRT FULL OR TAILORED
AGLINE		105	.10/.10	
AGRICOLA		40	.10/.15	
APILIT	SUBSCRIBERS	70	.15/.15	.05
	NON-SUBSCRIBERS	100	.25/.25	.15
APIPAT	SUBSCRIBERS	70	.15/.15	.05
	NON-SUBSCRIBERS	100	.25/.25	.15
ASI		110	.25/.35	
BANKER		90	.15/.15	
BIOCODES		45	.10/.10	
BIOSIS/BIO7479/BIO6973		65	.10/.20	
			.10 PRT TRIAL	
			.05 PRT ISSUE	
CAS77/CAS7276/CAS6771		68	.20/.20	.10
CASSI		60	.20/.90	.12
CHEMDEX1/CHEMDEX2/CHEMDEX3		125	.25/.25	.08
CIN		70	.20/.25	.10
CIS		110	.25/.35	
COLD		95	.25/.25	
COMPENDEX		95	.25/.35	.22
CRDS	SUBSCRIBERS	100	.13/.13	
CRECORD		120	.25/.25	
DBI		45	.25/.25	
EBIB		95	.20/.20	
EDB		65	.15/.25 (INTRODUCTORY OFFER)	
ELCOM		45	.10/.10	
ENERGYLINE		90	.20/.20	
ENVIRONLINE		90	.20/.20	
EPIA		95	.20/.20	
ERIC		40	.10/.15	
FEDEX		120	.20/.25	
FEDREG		105	.25/.25	
FSTA		65	.15/.25	
FOREST		100	.20/.20	
GEOREF		105	.25/.25	.10
GRANTS		70	.35/.35	
INFORM		75	.30/.40	
INSPEC/INSP6976		80	.30/.30	.10
LABORDOC		105	.20/.20	
LIBCON		120	.25/.25	

LISA		50	.10/.10	
MANAGEMENT		80	.25/.25	
MONITOR		90	.15/.15	
NDEX		90	.15/.15	
NTIS		45	.10/.15	
NUC/CODES		40	.10/.10	
ORBIT/ORBCHEM/ORBPAT		40	NA	
P/E NEWS	SUBSCRIBERS	105	.15/.15	.05
	NON-SUBSCRIBERS	105	.25/.25	.15
PESTDOC	SUBSCRIBERS	100	.13/.13	
PIE		50	.10/.10	
POWER		40	.10/.10	
PSYCINFO		65	.10/.15	
RINGDOC	SUBSCRIBERS	100	.13/.13	
SAE		95	.20/.20	
SAFETY		75	.15/.15	
SPORT		70	.15/.15	
SSIE		110	.25/.25	
SWRA		65	.10/.10	
TITUS		85	.20/.20	
TROPAG		70	.20/.20	
TULSA	MAJOR SUBSCRIBERS	75	.15/.15	
	MINOR SUBSCRIBERS	125	.50/.50	
USCLASS		60	.50/.50	
USGCA		105	.20/.20	
USPA		100	.25/.50 .75 PRT HIT 1.00 PRT ALL	
USRFP1/USRFP3		115	.50/.50	
USRFP2		115	.50/2.00	1.00
VETDOC	SUBSCRIBERS	100	.13/.13	
VOTES		90	.15/.15	
WATERLIT		80	.15/.15	
WPI	SUBSCRIBERS	100	.15/.15	
	NON-SUBSCRIBERS	125	.25/.25	
WPIL	SUBSCRIBERS	105	.15/.15 PRT FAM OR FULL .26 PRT CODE OR TAILORED	
	NON-SUBSCRIBERS	130	.25/.25 PRT FAM OR FULL .45 PRT CODE OR TAILORED	

- STORESEARCHES ARE CHARGED AT THE RATE OF $.05 PER TERM PER MONTH.
- NETWORK TELECOMMUNICATIONS CHARGES ARE $8/HR, FOR EITHER TELENET OR TYMNET.

(EFFECTIVE 1/82)

SYNORG

Scope:

Synthetic Organic Chemicals: United States Production and Sales (SYNORG) is a single volume annual publication of the U.S. International Trade Commission. It receives data from approximately 800 producers, and reports domestic commercial production and sales of synthetic organic chemicals and the raw materials from which they are made. Fifteen sections, organized by chemical classes, deal with: tar and tar crudes; crude products from petroleum and natural gas for chemical conversion; cyclic intermediates; dyes; organic pigments; medicinal chemicals; flavor and perfume materials; plastics and resin material; rubber-processing chemicals; elastomers; plasticizers; surface-active agents; pesticides and related products; miscellaneous end-use chemicals and chemical products; and miscellaneous cyclic and acyclic chemicals.

For each of these groups, three separate tables are provided. The first of these lists the total production and sales figures for those chemicals for which there are three or more significant producers. The second table lists the manufacturers for all chemicals (in terms of a code), and the third table defines the manufacturers code. The Commission also publishes monthly statistics on 110 of the most significant of these chemicals.

A companion publication entitled "Imports of Benzenoid Chemicals and Products, 19xx", is also available from the Commission. For this publication, the imported benzenoids are categorized in seven groups as follows: intermediates, finished products, dyes and pigments, medicinals and pharmaceuticals, flavor and perfume, and all other finished products. Various tables are provided for various groups showing imported quantities by chemical, invoice values by country of origin, etc.

Through 1975, data were reported by producers for only those items where the volume of production exceeded 1,000 pounds or where the value of sales exceeded $1,000. Beginning in 1976, these limits were raised to 5,000 pounds and $5,000 for most chemicals and 50,000 pounds and $50,000 for plastics and resin materials; the 1,000 pounds and $1,000 limits were retained for organic pigments, medicinal chemicals, flavor and perfume materials, rubber processing chemicals, and elastomers.

Access:

Available through the U.S. Government Printing Office.

Cost:

Cost varies with year of publication.

Sample Search/Output:

Not applicable.

Form No. CD-A1 Office of Management & Budget No. 73-R0002

RETURN TO
UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, D.C. 20436
BY APRIL 1, 1980

SYNTHETIC ORGANIC CHEMICALS

PRODUCTION AND SALES IN 1979
BY ORIGINAL MANUFACTURERS ONLY

COMPANY NAME ______________________
OFFICE ADDRESS ______________________
CITY ______________ STATE ____________ ZIP CODE ________
PLANT ______________ STATE ____________ ZIP CODE ________
If report covers more than one plant, please attach list of plant locations.

The information required in this questionnaire is being collected by the United States International Trade Commission under the authority of section 333 of the Tariff Act of 1930, as amended (19 U.S.C. 1333). The U.S. International Trade Commission is authorized to collect the data requested in this questionnaire under the provisions of section 332 of the Tariff Act of 1930, as amended (19 U.S.C. 1332). The data are being collected for the use of the U.S. International Trade Commission and for the use of the Domestic and International Business Administration of the Department of Commerce, which has the authority to collect such data in its own right under section 705 of the Defense Production Act of 1930, as amended (50 U.S.C. App. 2155), and to receive them from the U.S. International Trade Commission pursuant to 44 U.S.C. 3508(b)(4).

This report is mandatory and failure to reply as directed can result in a subpeona or other order to compel the submission of records or information in your possession.

Information supplied by you in this questionnaire or in connection therewith that qualifies as confidential business information within the meaning of the Freedom of Information Act [5 U.S.C. 552(b)(4)] will be so treated by the Commission and not disclosed except as may be required by law. Such information will not be published by the Commission in a manner that will reveal the individual operations of your firm.

IMPORTANT NOTICE: Please enter the necessary data in each of the enclosed sections and return one copy of each to the U.S. International Trade Commission without delay. Be sure each section is clearly identifies as the report from your company. Return this cover and the Directory of Manufacturers (Section XIX) with the last section you send in. The report must be signed by an offical of the Company.

1979

SCOPE OF THE REPORT

The complete report used by the U.S. International Trade Commission in compiling its annual report on the synthetic organic chemicals industry now consists of 19 sections. The first 15 sections are to be used in reporting data on the production and sales of synthetic organic chemicals and their raw materials. Section 16 is to be used for reporting synthetic organic chemicals which are not covered by the other sections of the report. Section 17 is to be used for reporting toll agreements. Section 18 is to be used for reporting barter agreements. Section 19 provides information for the Directory of Manufacturers. Only those sections pertaining to the chemicals and chemical products which are believed to be produced by your company are enclosed.

This report consists of the following sections:

I Tar, Tar Crudes, and Tar Pitches
II Primary Products from Petroleum and Natural Gas for Chemical Conversion
III Cyclic Intermediates
IV Dyes
V Organic Pigments
VI Medicinal Chemicals
VII Flavor and Perfume Materials
VIII Plastics and Resin Materials
IX Rubber-Processing Chemicals
X Elastomers (Synthetic Rubber)
XI Plasticizers
XII Surface-Active Agents
XIII Pesticides and Related Products
XIV Miscellaneous End-Use Chemicals and Chemical Products
XV Miscellaneous Cyclic and Acyclic Chemicals
XVI Other Synthetic Organic Chemicals
XVII Toll Agreements
XVIII Barter Agreements
XIX Directory of Manufacturers

DRAFT

35602000001

Waste Characterization Data Base

Acronym: None
Media sampled to generate data: Solid waste
process residuals
Type of data collection/monitoring: Point source data collection industrial process residuals
Data base status: Operational/ongoing

ABSTRACT: Data on the amount and composition of industrial chemical process residuals. Specific compound identification and concentrations. Includes information on generator of the sample. Samples are analyzed to determine significant materials present, regardless of whether or not they are on any of the pollutant parameter lists.

Non-pollutant parameters include:
- Chemical data
- Disposal
- Industry
- Location
- Manufacturer
- Physical data
- Production levels
- Sampling date
- Test/analysis method

Ongoing study time period is 10/01/80 to 09/30/80 (present)
Termination of data collection: Not anticipated

Frequency of data collection: as needed
once or twice per generator

Total estimated number of observations is 200.
Estimated annual increase of observations is 2000.

Data base includes: Raw data/observations
Summary or aggregate observations

Total number of stations or sources covered is 25.
Number currently contributing data is 12 month.
Number of facilities covered is 25.

Geographic coverage of data base: National
Location identifiers of station/source for each record are:
- State
- City
- Street address
- Project identifier
- complete facility identification

Facility identifiers include:
- Plant facility name
- Plant location

DRAFT

Street address
Dun and Bradstreet number number
Pollutant identification data are: Uncoded

Limitations: No lab evaluation samples have yet been developed.

Data collection and analysis procedures: Sampling plan documented
Collection method documented
Analysis method documented
QA procedures documented
Lab analysis based on EPA-approved or accepted methods.
Precision and accuracy estimates partially exist for only part of the data base
Edit procedures used but undocumented.

Data collected by: Self reporting in petitions
EPA lab - Environmental Monitoring Systems Lab-Las Vegas, and other Office of Research and Development Labs.
Contractor lab - various
Data analyzed by: EPA lab - Office of Research and Development Labs (including Environmental Monitoring System Lab-Las Vegas)
Contractor lab - various
EPA headquarters - Office of Solid Waste
Data base does not identify specific laboratory performing analysis.

Development of regulations or standards is the primary purpose for data collection.
Statutory authorization is P L 92-580/3007 (Resource Conservation and Recovery Act)
Form of available reports and outputs: Hand searchable as needed
Current regular users of data base: 15
Users: EPA headquarter offices - Office of Solid Waste
Confidentiality: Limits on access within EPA and outside agency for all data
Primary physical location of data: Headquarters office
Form of data storage: Original form (hardcopy, readings)
Data access: Manually

Contact - Subject matter:David Friedman (202) 755-9187
Contact - responsible EPA Office: Office of Solid Waste Hazardous & Industrial Waste Division (202) 755-9187

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Person completing form: David Friedman
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Address: 401 M St S.W. Washington, DC 20460
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Pollutants included in data base:
acetaldehyde 75-07-0
acetone 67-64-1
acetonitrile 75-05-8
acetophenone 98-86-2

NIOSH CRITERIA DOCUMENTS

Pub No.	Title	GPO Stock No.	Price	NTIS Stock No.	P/C Price	M/F Price
76-195	A Acetylene	017-033-00175-8	5.50	PB 267-068	11.50	4.50
77-112	A Acrylamide	017-033-00185-5	6.00	PB 273-871	14.50	4.50
✓78-116	Acrylonitrile	*	*	PB81-225-617	7.00	4.50
78-201	Aldrin/Dieldrin (Special Hazard Review)	*	*	PB 297-769	11.50	4.50
77-151	A Alkanes (C5-C8)	017-033-00213-4	6.00	PB 273-817	14.50	4.50
✓76-204	A Allyl Chloride	017-033-00186-3	5.50	PB 267-071	11.50	4.50
74-136	A Ammonia	017-033-00036-1	5.50	PB 246-699	13.00	4.50
78-216	A Antimony	*	*	PB81-226-060	14.50	4.50
74-110	A Arsenic, Inorganic	*	*	PB 228-151	13.00	4.50
75-149	Arsenic, Inorganic (Revised)	*	*	PB 246-701	14.50	4.50
72-10267	Asbestos	*	*	PB 209-510	14.50	4.50
✓77-169	Asbestos (Revised)	017-033-00229-1	5.50	PB 273-965	11.50	4.50
78-106	A Asphalt Fumes	017-033-00272-0	6.50	PB 277-333	16.00	4.50
74-137	Benzene	017-033-00038-7	6.00	PB 246-700	14.50	4.50
+	A Benzene (Revised)	NIOSH ONLY	*	*	*	*
✓80-109	Benzidine-based dyes (Special Hazard Review)	017-033-00354-8	4.25	PB81-225-633	10.00	4.50
77-166	A Benzoyl Peroxide	017-033-00221-5	5.50	PB 273-819	14.50	4.50
✓78-182	A Benzyl Chloride	017-033-00316-5	5.50	PB81-226-698	11.50	4.50
72-10268	A Beryllium	*	*	PB 210-806	13.00	4.50
+	Beryllium (Revised)	*	*	PB83-182-378	7.00	4.50
77-122	A Boron Trifluoride	017-033-00178-2	5.50	PB 274-747	11.50	4.50
76-192	A Cadmium	017-033-00206-1	5.50	PB 274-237	11.50	4.50
77-107	A Carbaryl	017-033-00196-1	7.00	PB 273-801	19.00	4.50
✓78-204	Carbon Black	*	*	PB81-225-625	13.00	4.50
76-194	A Carbon Dioxide	017-033-00199-5	6.50	PB 266-597	17.50	4.50
77-156	A Carbon Disulfide	017-033-00216-9	7.00	PB 274-199	17.50	4.50
73-11000	A Carbon Monoxide	*	*	PB 212-629	13.00	4.50
76-133	Carbon Tetrachloride	017-033-00176-6	6.50	PB 250-424	16.00	4.50
+	A Carbon Tetrachloride (Revised)	NIOSH ONLY	*	*	*	*
76-170	A Chlorine	*	*	PB 266-367	16.00	4.50
75-114	Chloroform	*	*	PB 246-695	14.50	4.50
+	A Chloroform (Revised)	NIOSH ONLY	*	*	*	*
77-210	A Chloroprene	017-033-00239-8	6.50	PB 274-777	17.50	4.50

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Pub No.	Title	GPO Stock No.	Price	NTIS Stock No.	P/C Price	M/F Price
73-11021	A Chromic Acid	*	*	PB 222-221	11.50	4.50
76-129	A Chromium (VI)	*	*	PB 248-595	19.00	4.50
78-163	Chrysene (Special Hazard Review)	*	*	PB81-225-641	10.00	4.50
✓ 78-191	Coal Gasification Plants	*	*	PB80-164-874	19.00	4.50
✓ 81-131	Coal Liquefaction: Vol. I--Summary (Occup. Hazard Assess.)	017-033-00390-4	3.75	PB81-242-877	7.00	4.50
✓ 81-132	Coal Liquefaction: Vol.II--(Occup. Hazard Assessment)	017-033-00391-2	7.00	PB81-242-885	16.00	4.50
✓ 78-107	A Coal Tar Products	017-033-00273-8	7.00	PB 276-917	17.50	4.50
82-107	Cobalt	017-033-00393-9	5.00	PB82-182-031	13.00	4.50
73-11016	A Coke Oven Emissions	*	*	PB 216-167	10.00	4.50
✓ 80-106	Confined Spaces, Working In	*	*	PB80-183-015	11.50	4.50
75-118	A Cotton Dust	*	*	PB 246-696	16.00	4.50
✓ 78-133	Cresol	017-033-00284-3	6.00	*	*	*
77-108	A Cyanide, Hydrogen and Cyanide Salts	017-033-00163-4	7.00	PB 266-230	19.00	4.50
78-200	DDT (Special Hazard Review)	*	*	PB81-226-656	19.00	4.50
✓ 83-109	Di-2-Ethylhexyl Phthalate ("DOP")					
	Respirator Quantitive Fit Testing (Special Occupational Hazard Review)	*	*	PB83-250-613	8.50	4.50
✓ 78-115	Dibromochloropropane	*	*	PB81-228-728	7.00	4.50
78-215	A Diisocyanates	*	*	PB81-226-615	16.00	4.50
✓ 78-131	Dinitro-Ortho-Cresol	*	*	PB80-175-870	16.00	4.50
77-226	A Dioxane	017-033-00254-1	7.00	PB 274-810	19.00	4.50
✓ 83-103	Draft Construction Safety Standards for Excavations, Volume I	*	*	PB84-100-569	13.00	4.50
	Volume II	*	*	PB83-233-353	25.00	4.50
76-128	A Elevated Work States, Emergency Egress from	*	*	PB 248-594	10.00	4.50
76-206	A Epichlorohydrin	017-033-00197-9	6.50	PB81-227-019	16.00	4.50
✓ 77-221	Ethylene Dibromide	017-033-00251-7	7.00	PB 276-621	19.00	4.50
76-139	A Ethylene Dichloride	OUT-OF-PRINT	----	-----------	-----	----
✓ 78-211	Ethylene Dichloride (1,2 Dichloroethane) (Revised)	*	*	PB80-176-092	8.50	4.50
77-200	Ethylene Oxide (Special Hazard Review)	*	*	PB 274-795	10.00	4.50
✓ 79-109	Ethylene Thiourea (Special Hazard Review)	*	*	PB81-224-206	11.50	4.50
✓ 77-152	Fibrous Glass	017-033-00214-2	5.50	PB 274-195	19.00	4.50
76-103	A Fluorides, Inorganic	017-033-00118-9	7.00	PB 246-692	19.00	4.50
✓ 77-193	A Fluorocarbon Polymers, Decomposition Products of	*	*	PB 274-727	13.00	4.50

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Pub No.	Title	GPO Stock No.	Price	NTIS Stock No.	P/C Price	M/F Price
✓ 77-126	Formaldehyde	*	*	PB 273-805	17.50	4.50
✓ 79-133	A Furfuryl Alcohol	*	*	PB80-176-050	10.00	4.50
78-166	A Glycidyl Ethers	017-033-00313-1	7.00	PB81-229-700	19.00	4.50
✓ 83-125	Hazardous Energy, Guidelines for Controlling During Maintenance & Servicing	017-033-00408-1	3.25	PB84-199-934	11.50	4.50
72-10269	A Hot Environments	*	*	PB 210-794	13.00	4.50
78-172	A Hydrazines	*	*	PB81-225-690	23.50	4.50
76-143	A Hydrogen Fluoride	017-033-00171-5	7.00	PB81-226-516	17.50	4.50
✓ 77-158	A Hydrogen Sulfide	017-033-00217-7	6.50	PB 274-196	16.00	4.50
78-155	A Hydroquinone	*	*	PB81-226-508	17.50	4.50
75-126	A Identification System for Occupationally Hazardous Materials	*	*	PB 246-698	10.00	4.50
76-142	A Isopropyl Alcohol	017-033-00165-1	6.00	PB 273-873	14.50	4.50
+	A Kepone	NIOSH ONLY				
78-173	A Ketones	*	*	PB80-176-076	22.00	4.50
73-11010	Lead, Inorganic	*	*	PB 214-265	13.00	4.50
78-158	Lead, Inorganic (Revised)	017-033-00306-8	7.00	PB81-225-278	19.00	4.50
76-168	A Logging from Felling to First Haul	*	*	PB 266-411	13.00	4.50
76-205	A Malathion	*	*	PB 267-070	17.50	4.50
73-11024	A Mercury, Inorganic	*	*	PB 222-223	14.50	4.50
76-148	A Methyl Alcohol	017-033-00191-0	6.00	PB 273-806	14.50	4.50
77-106	A Methyl Parathion	017-033-00202-9	7.00	PB 274-191	17.50	4.50
✓ 78-188	4,4'Methylene bis (2-chloroaniline) (Special Hazard Review)	*	*	PB 297-822	10.00	4.50
76-138	A Methylene Chloride	*	*	PB81-227-027	17.50	4.50
77-184	Nickel Carbonyl (Special Hazard Review)	017-033-00228-2	4.50	PB 273-795	8.50	4.50
77-164	A Nickel, Inorganic	017-033-00219-3	8.00	PB 274-201	23.50	4.50
76-141	A Nitric Acid	017-033-00169-3	5.00	PB81-227-217	11.50	4.50
78-212	A Nitriles	*	*	PB81-225-534	16.00	4.50
76-149	A Nitrogen, Oxides Of	*	*	PB81-226-995	19.00	4.50
78-167	A Nitroglycerin and Ethylene Glycol Dinitate	*	*	PB81-225-526	19.00	4.50
73-11001	Noise	*	*	PB 213-463	16.00	4.50
78-179	A o-Tolidine	*	*	PB81-227-084	11.50	4.50
77-115	A Organotin Compounds	017-033-00203-7	7.00	PB 274-766	17.50	4.50
76-190	A Parathion	017-033-00195-2	5.50	PB 274-192	13.00	4.50

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Pub No.		Title	GPO Stock No.	Price	NTIS Stock No.	P/C Price	M/F Price
78-174	A	Pesticides, Manufacture and Formulation	*	*	PB81-227-001	32.50	4.50
76-196	A	Phenol	*	*	PB 266-495	17.50	4.50
76-137	A	Phosgene	*	*	PB 267-514	14.50	4.50
✓ 77-225	A	Polychlorinated Biphenyls	017-033-00265-7	7.50	PB 276-849	20.50	4.50
77-192	A	Refined Petroleum Solvents	OUT OF PRINT	*	*	*	*
✓ 81-133		Rendering Processes, Animal (Occup. Hazard Assess)	017-033-00392-1	5.00	PB82-232-307	10.00	4.50
75-120		Silica, Crystalline	*	*	PB 246-697	14.50	4.50
76-105	A	Soduim Hydroxide	017-033-00110-3	5.50	PB 246-694	13.00	4.50
✓ 83-119		Styrene	*	*	PB84-148-295	22.00	4.50
74-111	A	Sulfur Dioxide	*	*	PB 228-152	13.00	4.50
+		Sulfur Dioxide (Revised)	*	*	PB83-182-485	7.00	4.50
74-128	A	Sulfuric Acid	*	*	PB 233-098	11.50	4.50
77-121	A	1,1,2,2-Tetrachloroethane	*	*	PB 273-802	16.00	4.50
76-185	A	Tetrachloroethylene (Perc)	*	*	PB 266-583	16.00	4.50
78-213	A	Thiols: N-Alkane Mono Cyclohexane, and Benzene	*	*	PB81-225-609	14.50	4.50
73-11023	A	Toluene	*	*	PB 222-219	13.00	4.50
73-11022		Toluene Diisocyanate (Revised: See Diisocyanates)	*	*	PB 222-220	13.00	4.50
76-184	A	1,1,1-Trichloroethane (Methyl Chloroform)	*	*	PB 267-069	17.50	4.50
73-11025	A	Trichloroethylene	*	*	PB 222-222	13.00	4.50
78-130		Trichloroethylene (Special Hazard Review)	*	*	PB81-226-987	11.50	4.50
✓ 77-227	A	Tungsten and Cemented Tungsten Carbide	017-033-00268-1	6.50	PB 275-594	17.50	4.50
73-11009	A	Ultraviolet Radiation	*	*	PB 214-268	13.00	4.50
77-222	A	Vanadium	017-033-00252-5	6.50	PB81-225-658	16.00	4.50
✓ 78-205	A	Vinyl Acetate	017-033-00362-9	5.00	PB80-176-993	11.50	4.50
+	A	Vinyl Chloride	NIOSH ONLY	*	*	*	*
+		Vinyl Halides	NEVER PRINTED	*	*	*	*
✓ 77-140	A	Waste Anesthetic Gases And Vapors	*	*	PB 274-238	19.00	4.50
75-168	A	Xylene	*	*	PB 246-702	13.00	4.50
76-104	A	Zinc Oxide	017-033-00109-0	5.50	PB 246-693	11.50	4.50

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OSHA REPORT: OHDS A                          U. S.  D E P A R T M E N T  O F  L A B O R

REGION      05: CHICAGO                      OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION                            APRIL 17, 1981
AREA     18001 COLUMBUS
CSHO    05519:   GRIFFING                                      INSPECTION SUMMARY
REPORT       : 13500
SIC       2851: PAINT, VARNISH, LACQR ETC
ESTABLISHMENT: DEAN AND BARRY PAINT COMPANY             INSP TYPE: GENERAL SCHEDULE            INSP PERIOD: 05/20/80 TO 05/20/80
      ADDRESS: 296 MARCONI BLVD

                                       #SIM                                       SAMPLE         EXPOSURE
FORM #     JOB TITLE                   EXP.        SUBSTANCE  NAME                TYPE  RESULTS   VALUE  UNIT   SEV   STANDARD CITED / TYPE
910152875  BATCH MIXER                   3    1591 LEAD, INORGANIC FUMES & D      P    TWA        0.019 M     0.37  19101025 L01    II    S

                                              0260 ARSENIC & COMPOUNDS (AS A      P    N/D

                                              0490 CADMIUM DUST (AS CD)           P    N/D

910152883  JANITOR                       1    1591 LEAD, INORGANIC FUMES & D      P    TWA        0.035 M     0.70

                                              0260 ARSENIC & COMPOUNDS (AS A      P    TWA        0.000 M     0.01

                                              0490 CADMIUM DUST (AS CD)           P    N/D

910152891  EMPLOYEE WHO STRIPS           3    1730 METHYLENE CHLORIDE (DICHL      P    TWA      132.000 P     0.26

910152909  TUB CLEANER                   4    1730 METHYLENE CHLORIDE (DICHL      P    TWA      151.460 P     0.30

910152925  MIXER                         3    0690 CHROMIUM, SOLUBLE CHROMIC      P    N/D

                                              1591 LEAD, INORGANIC FUMES & D      P    N/D

                                              0260 ARSENIC & COMPOUNDS (AS A      P    N/D

910152933  MIXER                         3    1591 LEAD, INORGANIC FUMES & D      P    TWA        0.012 M     0.24

                                              0690 CHROMIUM, SOLUBLE CHROMIC      P    TWA        0.004 M     0.01

910152941  MIXER                         3    1620 MANGANESE & COMPOUNDS (AS      P    CEILING    0.120 M     0.02

910152917  POURER                        1    2037 PETROLEUM DISTILLATES (NA      P    TWA      148.000 M     0.07
OSHA REPORT: OHDS 4                    U. S.  D E P A R T M E N T  O F  L A B O R

REGION      05: CHICAGO                OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION                    APRIL 17, 1981
AREA      1800: COLUMBUS
CSHO     K8492:    KENNEDY                          INSPECTION SUMMARY
REPORT       : 00100
SIC       7216: DRY CLEANING PLANTS
ESTABLISHMENT: TEXTILE-TECH INC DBA BEECHWOLD           INSP TYPE: GENERAL SCHEDULE              INSP PERIOD: 07/08/80 TO 07/29/80
      ADDRESS: 161 THURMAN AVE REAR

                                         #SIM                                 SAMPLE            EXPOSURE
FORM #     JOB TITLE                     EXP.        SUBSTANCE  NAME          TYPE  RESULTS    VALUE  UNIT   SEV    STANDARD CITED / TYPE
910146966  WORKER DRYER OPERATO            1    2020 PERCHLOROETHYLENE (TETRAC   P   TWA         5.800 P    0.06

                                                0570 CARBON TETRACHLORIDE - SK   P   N/D

                                                2490 TRICHLOROETHYLENE           P   N/D
970002580
                                           1    2020 PERCHLOROETHYLENE (TETRAC   S             100.000 P

                                           1    2490 TRICHLOROETHYLENE           S               0.000 P
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OSHA REPORT:  OHDS A                       U. S.   D E P A R T M E N T   O F   L A B O R

REGION      05: CHICAGO                    OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION                         APRIL 17, 1981
AREA      1800: COLUMBUS
CSHO    T68761:   THOMAS                                   INSPECTION SUMMARY
REPORT        : 03800
SIC       3322: MALLEABLE IRON FOUNDRIES
ESTABLISHMENT: J 6 CASTINGS OPERATIONS DRESSE          INSP TYPE: COMPLAINT                    INSP PERIOD: 08/14/79 TO 08/17/79
      ADDRESS: 560 SOUTH LIBERTY ROAD

                                    #SIM                                      SAMPLE            EXPOSURE
FORM #      JOB TITLE               EXP.        SUBSTANCE  NAME               TYPE  RESULTS    VALUE  UNIT  SEV   STANDARD CITED / TYPE

910050392   SHAKEOUT MAN              1      9010 SILICA (QUARTZ), RESPIRAB   P    N/D

910050400   SHAKE OUT OPERATOR        1      9010 SILICA (QUARTZ), RESPIRAB   P    N/D

910050416   COLD SET CORE MAKER       1      1290 FORMALDEHYDE                P    CEILING     0.260 P    0.05

                                             1013 CORUNDUM (A12O3)            P    CEILING     0.100 M    0.50

910050426   CASTING STOCKMAN          1      1720 METHYL CHLOROFORM           P    N/D

                                             2490 TRICHLOROETHYLENE           P    TWA        81.610 P    0.82

910050434   COLD SET CORE MAKER       1      2220 PYRIDINE                    P    N/D

910050442   PEP SET CORE FINISHE      4      1720 METHYL CHLOROFORM           P    TWA        33.570 P    0.10

                                             2490 TRICHLOROETHYLENE           P    TWA        43.350 P    0.43

910050459   OIL SAND CORE FINISH      1      1720 METHYL CHLOROFORM           P    TWA        68.500 P    0.20
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

Adapted from:

BIBLIOGRAPHY OF PROTECTIVE CLOTHING DATA

April 28, 1982

Protective Clothing Working Group
Office of Pesticide Programs
United States Environmental Protection Agency
Washington, DC 20460

Prepared by:

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